THE MINERAL INDUSTRY OF THE BRITISH EMPIRE AND FOREIGN COUNTRIES

GEMSTONES

LONDON
PRINTED AND PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. STATIONERY OFFICE at the following addresses
Adastral House, Kingsway, London, W.C.2; 120, George Street, Edinburgh 2
York Street, Manchester 1; 1, St. Andrew's Crescent, Cardiff
15, Donegall Square West, Belfast
or through any Bookseller

1933

Price 2s. 6d. net

61-154

CONTENTS.

INTRODUCTION.

Gemstones include those minerals which are used for personal adornment and for purposes of ornamentation on account of their beauty and decorative value. Some of them have been employed in this way since the early days of civilization, and it is said that some fourteen different varieties were known more than seven thousand years before the Christian era.

Those gemstones which are of rare occurrence are of exceptionally high value and are usually referred to as precious stones, while others of less value are reckoned as semi-precious. It is usual to restrict the term "precious" to the most highly prized varieties of pearl, diamond, emerald, ruby, sapphire and precious or "noble" opal, but no line can be drawn between the semi-precious and ornamental stones which ultimately grade into merely decorative building stones. Even the emerald, ruby, sapphire and precious opal are only exceptionally beautiful and rare varieties of quite common minerals.

The qualities which chiefly determine the suitability of a stone for use as a gem are beauty or decorative value, rarity and durability, but one of the most potent factors affecting the extent to which the stone is used, and hence its value, is the fluctuating unknown quantity depending upon the vogue of the period, dictated by fashion.

The beauty of a stone may lie chiefly in its colour or play of colours, but it may also be due, in a transparent gemstone, to its brilliancy or its "fire", and these are dependent upon the degree or extent to which light passing through the stone is refracted by it. Brilliancy is due to high refractive power and "fire" to high dispersive power. Diamond, for instance, possesses both these properties in a marked degree; its brilliance exceeds that of any other gemstone, and a faceted diamond displays all the colours of the rainbow when viewed from slightly different angles.

Rays of white light entering the brilliant at the front are split up into their component colours which, owing to wide differences between the refractive indices for different colours, are widely dispersed; they are then reflected from the back of the stone and emerge as separate rays of red, blue, yellow, and other coloured light. The brilliant is so cut as to make use of this phenomenon to the greatest possible extent. The cutting of facets upon a gemstone according to scientific principles is a comparatively modern development which has very greatly enhanced the appearance of the transparent stones that lend themselves to this treatment.

Other effects which add beauty to the appearance of some stones are those of dichroism (or pleochroism), due to variation in absorption of light with change of direction. Stones possessing this property exhibit a change in colour when viewed in different directions; this is well illustrated by tourmaline.

Certain stones gain in attractiveness by their lack of homogeneity, and some exhibit a silky sheen due to the disposition of minute tubes or cavities within the crystal. Among such may be mentioned star rubies and star sapphires, in which minute tubes are arranged at angles of 60° in planes perpendicular to the long axis of the crystal, the phenomenon being called asterism owing to the star-like appearance of the six rays which are reflected from the interior of the stone.

In other stones, such as some varieties of quartz and chrysoberyl, the tubes are parallel to one another, and one broad beam only is displayed; such stones are known as " cat's-eye " and the phenomenon is called chatoyance. A somewhat similar phenomenon is the pearly sheen of moonstone, due to internal reflections from twin lamellae.

The remarkably beautiful effects seen in the play of colours of precious opal is due to interference of light which takes place at the surfaces of numerous films of material of slightly different optical character which have formed within the stone.

In opaque or translucent stones the attractiveness lies chiefly in the colour as in turquoise and lapis lazuli, or the arrangements of bands of colour, as for example in malachite and agate.

The second qualification of a precious stone, rarity, calls for little comment, for evidently no common thing can be " precious." The rarity may, however, be more apparent than real, for, as will appear later, the number of stones marketed in the case of diamond is strictly limited by the producers. Emerald, the most precious of all gemstones except pearl, owes much of its high value to the extreme rarity of good stones. Not long ago it was feared that the rarity of some precious stones, especially pearl, ruby and sapphire, would be nullified by the production of synthetic stones, but even the best of these can be detected by an expert, and the value of the natural stones is unimpaired.

In the matter of durability, as a general rule the value of an ornament will be adversely affected if it is not both physically and chemically capable of withstanding ordinary wear and tear. Jewellery ornaments are usually highly polished and should be hard enough to resist the abrasion which is encountered in ordinary usage, or their beauty will suffer. Some gemstones are rather porous and may be impaired by contact with grease or water. Pearl, turquoise and opal are liable to abrasion and are porous; they therefore lack this quality of durability and must be treated with care. Among other stones which might enjoy a greater reputation as gems were it not for their comparative softness are demantoid garnet (often miscalled " olivine " by jewellers), benitoite, apatite, sphene, peridot and fluorspar.

The taste of the public is an all-important factor in determining the value of a gemstone, and this is liable to change. Only extremely rare stones are to some extent outside the influence of fashion, for rarity is a standard by which value can be judged, whereas there are no standards of beauty.

Amethyst and deep red garnet were used in jewellery to a considerable extent in Victorian days, although quite common stones; to-day, however, they are seldom used. Only a few years ago rubies fell into disfavour and were seldom seen in jewellers' shop windows; to-day they are enjoying a great revival of vogue. Emerald, opal, peridot, aquamarine and cat's-eye are others which have suffered these vicissitudes at one time or another.

In some instances stones make a stronger appeal in one locality than another, and oriental nations differ in their taste from western nations. Thus in China, jade has always been esteemed above all other stones, while tourmaline is perhaps more favoured in the United States than elsewhere. Inferior crystals of beryl and other stones find a market in India where they are carved into ornaments which appeal to the oriental taste.

The jewellery trade is very conservative in its choice of precious stones, and very few of the attempts to popularize fresh varieties have met with success, even though the stones may appear to possess all the necessary qualities; thus, it seems rather strange that zircon does not enjoy a greater popularity. So marked is this conservatism that in order to create a demand for the less popular stones, such names as "Brazilian sapphire," "Uralian emerald," "Cape ruby," "Matura diamond," and a host of others have been applied to such of them as bear some resemblance in colour to the well-known stones whose names have been copied. In this way a very large number of most confusing synonyms grew up, many of which have in the past attained common use in the trade.* A movement is now on foot in this country to restrict the number of these so as to bring the terminology of the gem trader into line with that of the mineralogist, and at the International Congress of Jewellers held in London in 1930, and in Rome in 1933, some definite steps were taken to attain this end.

Identification.—The methods adopted for the identification of gemstones are largely the same as those employed for other minerals and cannot be described in detail here.† If the stone is uncut, its crystalline form and hardness will very often give the clue to its identity, but if cut, the specific gravity, refractive indices, birefringence and dichroism are the main diagnostic features. Chemical tests cannot be employed without danger of injury to the stone, and hardness tests can only be applied with caution. If the stone is in a setting it may not be possible to identify it with certainty without removing it from the setting.

*** A comprehensive glossary of synonyms may be found in Gems and Precious Stones in 1917, by W. T. Schaller; Min. Res. U.S., 1917, Part 2, pp. 147–168.**

† For detailed information the textbooks mentioned in the references to technical literature (p. 120) should be consulted.

Simple modifications of more elaborate scientific instruments are often of use in gem determination. A small pocket refractometer with a fixed scale, such as that devised by Dr. Herbert Smith, or one of the modern improved forms of the same, is very convenient for ascertaining the refractive index and birefringence, and may often be used with a stone in its setting. A small dichroscope is useful for observing the phenomenon of dichroism. Heavy liquids such as bromoform (specific gravity about 2·88) and methylene iodide (specific gravity about 3·32) are very convenient aids to the determination of specific gravity.

In exceptional cases it has been found convenient to employ X-rays and cathode rays in the determination of gem minerals, especially for detecting doublets and for discriminating between natural and artificial stones.

The Carat.—The unit of weight for all precious stones is the *carat*, but until quite recently considerable confusion was caused by the fact that the weights of the carats used at different centres varied considerably. The London carat (Board of Trade, 1888), for instance, which was widely used, was equal to 205·304 milligrammes, and the weights of stones were recorded in carats and fractions of a carat; thus $2\frac{1}{8}\frac{1}{16}\frac{1}{64}$ carats, etc. The older English carat was equal to 205·409 mg., but there was great variation in the weights used by different gem dealers.*

Practically all countries have now agreed to use the *metric carat* of 200 milligrams (0·2 gm.) as the standard. Only in the statistical records of British Guiana is the older carat retained. In the present document the metric carat only is used in the statistical tables.

In order to give some idea of the size of diamonds of different caratage, it may be taken that a brilliant-cut diamond of 1 carat measures approximately $\frac{1}{4}$ inch across, while one of 5 carats measures nearly $\frac{1}{2}$ inch.

MINERALS USED AS GEMSTONES.

At the present time the number of mineral substances used for decorative purposes is large, but most of them are minor varieties and the number of separate mineral species probably does not greatly exceed fifty. They do not form any natural group of substances, and cannot therefore be described in any natural order.

Diamond.—Diamond, which is generally acknowledged to be the chief of all the precious stones, is richly endowed with all the qualities required of these ornaments. Chemically it consists of the element carbon in a very pure state, and while it will take fire and burn on heating in an atmosphere of oxygen like any other form of carbon, it is otherwise extremely stable and not at all liable to alteration.

Notes on the weight of the "Cullinan" diamond, and on the value of the carat weight, by L. J. Spencer; Min. Mag., 1910, 15, 318–326.

Diamond crystallizes in the cubic system, generally in the form of an octahedron and sometimes of a cube, but many modifications of these simple forms are frequently met with, including various twinned forms. The common spinel-twin is usually known in the trade as a *macle*. This has the appearance of an octahedron which has been split into two parts parallel to one of the faces and then joined together again on the same surface after one part has been rotated through half a circle. Natural crystals are very seldom simple and perfect octahedra; the edges and corners are generally rounded and the octahedron faces small, so that the stones assume a somewhat spherical shape. Crystals are usually unequally developed in different directions, and this sometimes gives rise to somewhat tabular stones. The faces of crystals often show equilateral triangular markings.

Pure diamond is colourless and transparent, but traces of impurities may impart colour to the stones. Very impure stones may be deeply coloured brown or even black, and such are practically useless as precious stones. Yellowish and off-colour stones are relatively abundant and are chiefly esteemed in oriental countries, but those which are colourless or have a faint bluish tinge are highly esteemed universally. A coloured diamond, red, blue, green, violet, etc., is known as a " fancy " stone, and if the colour is pleasing and uniform, may be very highly valued.

The colour of diamonds, even if originally yellow or brown, can often be changed to green by submitting them to direct alpha radiation from radium salts or radium emanation. The green colour is apparently light-permanent, but the original colour may be restored by heating the stone to 500° C. or by recutting.

Diamond is the hardest of all minerals, for it will scratch every other stone, being graded as No. 10 in Mohs's scale. It therefore resists abrasion in use and provides the best material for the fashioning of other stones. The hardness varies somewhat in different directions in the crystal, being greatest in the directions parallel to the crystallographic axes. Hardness, however, is frequently confused with toughness in the public mind; but while it is extremely hard, diamond is also quite a brittle mineral, and the popular fallacy that it will resist even a light blow from a hammer on an anvil has led to the destruction of not a few valuable stones.

There are planes of weakness in most crystals, known as cleavage planes, which are directions along which the crystals can most readily be split so as to yield a plane surface. In diamond there are directions of perfect cleavage parallel to the octahedron faces, and this fact is made use of in fashioning brilliants.

The lustre of diamond is characteristic of this stone; it is of the most brilliant type and is known as adamantine. The refractive index, or power of bending a beam of light, is very high (2·4175 for yellow, or sodium light) and is constant for all directions in the crystal, while the dispersion, or difference in power of bending light of different wave lengths (i.e. different colours), is also very high, surpassing that of all other colourless stones. These properties, as has been stated above, give to the diamond its exceptional brilliance and " fire " when cut and polished.

The density of diamond is slightly variable in different specimens, but generally lies between 3·52 and 3·53 times that of pure water. It is highly incompressible, its thermal expansion is very low, it is a good conductor of heat, and its electrical conductivity varies according to the state of purity, pure diamond being a non-conductor. Diamond is transparent to X-rays and becomes phosphorescent when exposed to the action of radium; it tends to turn green under the latter treatment.

Diamond often occurs in a form unsuitable for gem purposes. A variety very commonly met with is dark brown, while others are grey or black and translucent or opaque. Such material, known as *bort*, is largely used in the crushed condition for cutting and polishing gemstones and for other abrasive purposes. Some bort consists of crystalline aggregates while other appears to be compact. A special variety of diamond peculiar to Brazil is known as *carbonado* or " carbon "; it is black or grey in colour, consists of minute crystalline aggregates and is slightly porous, with a lower density than precious diamond. It is largely employed in the crowns of drills used for penetrating hard rock.

Notes on some world-famous diamonds will be found on pp. 48, 50, 68, 105 and 118.

Ruby and Sapphire.—These very beautiful stones, which differ only in colour, are varieties of the mineral corundum. The colour of corundum is exceedingly variable, but the name ruby is reserved for the red variety and sapphire for the blue. Gem corundum may be colourless, yellow, green or purple and is very commonly parti-coloured.

Corundum is the crystalline form of alumina or oxide of aluminium (Al_2O_3), but the common variety is generally impure. It crystallizes in the trigonal system, usually either in the form of a six-sided prism with blunt ends or in the form of two rather elongated hexagonal pyramids joined at their bases. Gem varieties are of course those which are clear, transparent, free from flaws, and of good colour.

Corundum is next to diamond in hardness, being No. 9 in Mohs's scale, and its specific gravity is about 4·0. Owing to its type of symmetry corundum is doubly refracting, but in the direction parallel to the edge of the prism it is singly refracting. The mean of the refractive indices is 1·76 and the double refraction is low; about 0·008. The dispersion is also low, and in consequence sapphire and ruby display but little " fire."

Corundum is strongly dichroic, especially in the varieties ruby and sapphire. Ruby shows shades of red and purplish red, while sapphire shows blue and yellowish blue hues for the directions of the ordinary and extraordinary rays respectively. This fact influences the direction of cutting. Corundum has no true cleavage, but there is a marked tendency for parting to occur parallel to the basal plane, apparently due to incipient decomposition, which would not be present in a stone of gem quality.

Ruby is most highly prized when it approaches the carmine-rose shade known as " pigeon's blood " red, and the red colour is believed to be due to the presence of traces of chromium. Sapphire is most valued when the colour is a deep royal blue; the blue is said to be due to traces of titanium. Colourless corundum is called " white sapphire," yellow corundum is sometimes called " oriental topaz " (in Ceylon, " king topaz ") while green and purple shades are sometimes described as " oriental emerald " and " oriental amethyst " respectively. All are sometimes called " sapphire."

Sapphire, like the diamond, also changes colour (usually to a golden or canary yellow) on exposure to radium radiation, but in this case the colour is produced by beta and gamma radiation and is not light-permanent.

Both ruby and sapphire possess a peculiar, faint, fibrous structure or silky blemish, noticeable only to the practised eye, which varies in stones from different localities and enables an expert to determine the source of the stone which he is examining. An extreme case of this silky appearance is that which produces the varieties known as *star ruby* and *star sapphire*, in which the stones are translucent and display the curious optical effect of six rays of white light radiating from a centre.

A large crystal of fine ruby is a great rarity, for although ruby and sapphire are of the same material, the crystals of ruby are usually much smaller, stones of 5 carats being considered very important sizes. A fine ruby of 10 carats would be even more valuable than an emerald of similar size and quality. The corundum gems are frequently used as watch pivots, but " synthetic " stones have largely replaced the natural ones for this purpose in recent years.

Beryl and Emerald.—Like ruby and sapphire, beryl and emerald are merely differently coloured varieties of the same mineral, of which the mineralogical name is beryl. Beryl is a silicate of beryllium and aluminium having the chemical formula $3BeO.Al_2O_3.6SiO_2$ but the composition is rather variable. Emerald is that variety of beryl which possesses the well-known emerald-green colour, said to be due to the presence of chromium.

Beryl crystallizes in the hexagonal system in the form of six-sided prisms usually with blunt terminations. It is variable in colour, but except in the emerald variety the colours are always rather pale, the principal shades being sea-green, bluish green, yellowish green, pale yellow, pale blue, colourless, rose-red and pink. Beryl has a specific gravity of from 2·6 to 2·8 and a hardness between 7 and 8. Its mean refractive index is 1·58, and the double refraction is low; about 0·006. Dispersion is also very low so that the stone lacks both brilliance and "fire". Dichroism is only marked in the deeply coloured varieties. The chief attraction of the stone therefore lies in the colour and limpidity.

Aquamarine is the name applied by the jeweller to the sea-green and bluish stones; yellowish green stones are sometimes called "aquamarine chrysolite" while yellow beryl is known as *golden beryl* or *heliodor*; pink stones are called *morganite* in the United States.

Emerald is the most valuable of precious stones (excepting pearl) because of the extreme rarity of really fine crystals of good colour, unflawed emeralds of more than a few carats being practically unknown. A number of very large but imperfect stones are in existence; one in the possession of the Duke of Devonshire is an almost perfect crystal weighing 1,384 metric carats but very badly flawed, and a better stone of 161 metric carats is in the Mineral Gallery of the British Museum. The finest cut emerald in existence is said to be that formerly in the Russian Crown Jewels, which weighed 30 carats.

Aquamarine and the other varieties of beryl are much more common and rank only as semi-precious stones. Quite flawless crystals often attain considerable size, sometimes weighing many pounds.

Opal.—Opal differs from other precious stones in many respects, but mainly because its beauty depends on the play of colours it exhibits, whereas most others display one uniform tint. It is amorphous and translucent and must therefore be viewed by reflected light, whereas most gemstones are perfectly clear and transparent crystals.

Opal consists of hydrated silica and is probably a dried gel which developed cracks on drying, the cracks being subsequently filled with material of similar composition introduced in solution. It therefore lacks homogeneity, and it is to the fact that light is reflected and refracted from myriads of films within the stone that the play of colours is due. It is not very hard ($5\frac{1}{2}$ to $6\frac{1}{2}$) and it is brittle and of low specific gravity (1·9 to 2·3). It occurs chiefly in nodules and encrustations and is of very variable colour and appearance.

In *white opal* the body colour is generally milky-white or pearly-grey, but many other shades are sometimes met with. In the *black opal* the body colour is very dark greyish blue, almost black, which throws up the flashes of colour with great effect, so that these stones are much esteemed. *Fire opal* or *flame opal* is a more transparent variety, of reddish yellow colour with a particularly fiery play of colour. Many other varieties are recognized but in all types of precious opal the play of colours is remarkably vivid. It is, however, a stone which exhibits a greater diversity of type and quality than any other; and although at present it enjoys a fair popularity, the superstition that it is unlucky still influences the demand. Being rather soft and somewhat porous, it needs careful preservation.

The grading and valuation of opal is an art ~~in which great skill and experience are necessary as~~ so many factors have to ~~be taken into~~ account. Value is based on colour, pattern, fire and soundness, and the weight of a large piece is not necessarily a guide to its value, which can only be computed by estimating the number, size and quality of stones that can be cut from it. A fine opal is a stone of great beauty and considerable value.

Turquoise.—This is a massive or compact stone which is almost opaque and therefore always viewed by reflected light. It is a complex hydrated phosphate of aluminium and copper and occurs as veins and irregular masses. The colour is typically pale blue, but may be slightly greenish or yellowish-blue; in some stones the colour is liable to fade in course of time. The lustre is waxy, hardness about 5½ and specific gravity rather variable from 2·75 to 2·89. The stone is somewhat porous and liable to discoloration by absorption of grease. Although at one time largely used in a gold setting, with which the tint harmonized rather pleasingly, it has fallen into disfavour of recent years.

Two minerals rather similar to turquoise are *variscite*, a phosphate of aluminium, which has specific gravity 2·55, hardness less than 5, vitreous lustre and rather a greenish-blue colour, and *odontolite* or *bone turquoise*, the fossil teeth of animals, coloured blue by vivianite. Bone turquoise (sp. gr. 3 to 3·5) is heavier than true turquoise and generally shows the organic structure of the original substance clearly on magnification.

Jadeite and nephrite.—Another translucent stone is that known to the jeweller as "jade." Here there is some confusion of names, for "jade" includes both *jadeite* and *nephrite* as well as a variety of other greenish minerals such as *saussurite*, *green garnet* and *bowenite*, which are of somewhat similar appearance to jadeite.

Jadeite is a silicate of sodium and aluminium belonging to the pryroxene group of minerals, and analogous to spodumene (p. 15). The colour varies from white to apple- or emerald-green and sometimes mauve, but is not uniform. The mineral, which is compact and tough, has a hardness of 6½ to 7, a specific gravity of 3·3, a mean refractive index of 1·67 and a lustre which is between vitreous and pearly. Jadeite is the most highly valued stone among far eastern nations, by whom it is carved with great skill into ornaments or turned into beads. Commercial supplies are obtained only from Burma.

Nephrite is a tough, massive, compact mineral of very similar appearance to jadeite, but usually of a dark green colour. It is a silicate of magnesium and calcium with iron, and belongs to the amphibole group of minerals, being a compact-fibrous variety of actinolite. With specific gravity about 3 it is lighter than jadeite but has about the same hardness. The refractive index is somewhat lower (mean 1·62) and it is noticeably dichroic under the microscope. Nephrite is much more abundant than jadeite and was worked thousands of years before the Christian era by primitive man, who found the mineral particularly suitable for his axe-heads, chisels and other tools on account of its extreme toughness. Many examples have been found in New Zealand, in the ancient lake-dwellings of Switzerland and elsewhere.

Topaz.—Topaz is a complex hydrated silicate of aluminium containing a variable amount of fluorine, and crystallizes in the orthorhombic system, often as fine transparent prismatic crystals showing terminal faces at one end. It has a perfect cleavage parallel to the base and is easily broken along this plane. Its hardness is 8, specific gravity 3·5 to 3·6, mean index of refraction 1·62 to 1·63, with weak double refraction (about 0·009) but fair dispersion (0·014), so that it exhibits some " fire " when faceted.

Common colourless topaz is a fairly abundant mineral, but the precious variety is coloured wine-yellow. Occasionally blue, pale green, mauve, red or pink topaz are met with and these also are used for gem purposes. Coloured varieties exhibit marked dichroism. Crystals of the colourless variety sometimes attain considerable size and may weigh many pounds.

Some Siberian topaz loses its wine-yellow colour on exposure to sunlight and becomes a dirty white, while the yellow Brazilian topaz is often artificially converted to a rose-pink shade by careful heating; such stones exhibit greater dichroism than natural pink stones.

Although it is a durable stone of considerable beauty which will take a fine polish, topaz is not very popular at the present time.

In the jewellery trade, at one time, almost any yellow stone was known as topaz. " Oriental topaz " is yellow corundum; " occidental topaz," " Bohemian topaz," " Spanish topaz " and " quartz topaz " are yellow quartz (citrine); " Brazilian sapphire " and " Brazilian ruby " are blue and red topaz respectively; and " false topaz " is yellow fluorspar. The true gem topaz is generally known as " Brazilian topaz," if the colour is yellow, whatever its source may have been.

Tourmaline.—Tourmaline is a beautiful semi-precious stone which exhibits a great variety of tints. It is a complex borosilicate of variable composition which crystallizes in the trigonal system in the form of prisms, usually vertically striated, very often nearly triangular in cross section, and with the two ends bearing different crystal forms. The specific gravity is 2·9 to 3·2, hardness 7 to 7½, mean refractive index 1·63; birefringence is strong (0·20), and dichroism very strong. The gem varieties are transparent with vitreous lustre and no cleavage.

Common iron-rich tourmaline or *schorl* is black, the magnesium-rich variety being brown, but it is mostly the kinds rich in alkali metals that find a use in jewellery. The colour is often green or bluish green, sometimes greenish yellow, honey-yellow, light or dark blue, violet, red, pink or colourless. Crystals may be zoned with different colours, and these may be vertical or horizontal; stones which are green at one end and pink at the other are often met with, while some green stones have a red core and some red stones have a green core.

Although tourmaline does not form such large crystals as beryl, it often attains a fair size, and is most often used as the large centre piece of a pendant or brooch, being rather too soft for use in rings. It is a stone which is not greatly esteemed, but it enjoys a fair reputation in the United States, where some very fine stones are obtained. The very marked dichroism of tourmaline is one of its most characteristic features. Colourless stones are known as *achroite*, pink and red stones as *rubellite* or "Siberian ruby," indigo-blue as *indicolite*, green stones have sometimes been called "Brazilian emerald," yellow-green "Brazilian peridot" or "Ceylon chrysolite," honey-yellow "Ceylon peridot," and blue "Brazilian sapphire."

Spinel.—Spinel is essentially magnesium aluminate with the formula $MgO.Al_2O_3$, but the magnesium may be replaced by ferrous iron, zinc, manganese or cobalt, and the aluminium by ferric iron or chromium. The crystals are cubic and generally take the form of octahedra, often twins. The specific gravity of gem varieties ranges from 3·5 to 3·7, the hardness is about 8, and the refractive index about 1·72, gem varieties being transparent. The hue is variable, every colour being represented. Deep red stones have the lowest specific gravity and deep blue the highest. The principal variety used as a gem is the rose-red stone called *balas-ruby* which is rather similar to ruby in appearance, the deeper shades being known as *ruby-spinel* or *spinel-ruby*. The orange-tinted variety is called *rubicelle* and the purple-tinted stones *almandine-spinel*. Blue spinel is known as *sapphire-spinel* and even the black spinel, *pleonaste*, is also occasionally used in jewellery.

Being usually deeply coloured, spinel is not often sufficiently transparent for use as a large stone, but is quite suitable for rings; it is, however, not so attractive as ruby or sapphire, and is not in much demand. Two very fine ruby-spinels are in the British regalia. One of them, which is polished but uncut, weighs 352 carats, and is said to be the largest of these stones known; the other, now set in the English crown, is said to have been given to the Black Prince in 1367 after the battle of Najera.

Garnet.—The garnet group of minerals forms an isomorphous series of double silicates of two sets of bases, one divalent and the other trivalent. The divalent bases may be CaO, MgO, FeO or MnO and the trivalent ones Al_2O_3, Cr_2O_3 or Fe_2O_3, the molecular proportions being $3:1:3SiO_2$. The group includes many members, several of which have been used as gems. They crystallize in the cubic system, often in the form of a dodecahedron, and are therefore isotropic, the refractive index varying from 1·7 to 1·89 and the specific gravity from 3·4 to 4·3 according to the species. The gem varieties are transparent, although sometimes very dark, and the colours vary considerably, all except blue being represented.

The principal gem varieties are *pyrope*, otherwise known as "Bohemian garnet", "Cape ruby" or "Arizona ruby", a blood red stone which often passes as ruby, but which is always tinged with yellow; *almandine*, or "carbuncle", a deep crimson variety tinged with violet which shows a characteristic absorption-spectrum; *rhodolite*, which is intermediate between pyrope and almandine; *hessonite*, often known as "cinnamon stone", and sometimes incorrectly as "hyacinth" or "jacinth" (which is really a variety of zircon), the orange or yellow variety of the garnet *grossular* with a somewhat granular structure; *demantoid*, incorrectly known to jewellers as "olivine" or "Uralian emerald", a beautiful green gemstone which is an uncommon variety of common *andradite* garnet; *spessartine*, the orange-red manganese garnet, very rarely large and perfect enough to be cut as a gem; *grossular*, which in a massive form, pale green in colour, is used as a substitute for jade; and several minor varieties.

Of these pyrope at one time was largely used in jewellery but is seldom now employed, probably largely on account of its abundance. Almandine is used in India, but not to any extent in western countries, and hessonite only very seldom. Demantoid is a remarkable stone which surpasses even diamond in colour-dispersion, and has an almost adamantine lustre, but is too soft to use as a ring stone.

The harder varieties of garnet were often used as pivots for watches and various instruments of precision before the introduction of artificial corundum.

Zircon.—Zircon, which in its various forms is known to jewellers as *jargoon*, *hyacinth* or *jacinth*, is a beautiful gemstone which deserves a greater popularity. It consists of zirconium silicate and crystallizes in the tetragonal system as short square prisms terminated by pyramids. Gem varieties are quite transparent, with hardness 7½, specific gravity variable from 4 to 4·86, refractive index also variable from about 1·8 to 2·0, birefringence strong, dispersion strong and dichroism weak. Isotropic varieties are sometimes met with. The lustre is almost adamantine and there is no distinct cleavage.

The colour of gem zircon is very variable, yellowish red, golden brown and green shades being the more common, while red, blue and colourless zircon is less often encountered. *Hyacinth* or *jacinth* are names applied to the yellowish red stones, which are the same colour as the garnet "cinnamon stone", with which they are frequently confused. Straw-yellow to colourless stones are known as *jargoon*, while absolutely colourless stones from Ceylon are known as " Matura diamonds ".

In view of the great variation in specific gravity and the changes which zircon undergoes on heating, it has been suggested that three modifications of the mineral exist, one having a permanent specific gravity of 4·0, another 4·7, and the third normally about 4·0 but subject to increase by heating. Pure leaf-green stones have the lowest, and colourless stones the highest specific gravities. The colour of zircon changes on heating, nearly all stones becoming lighter in shade; some become almost colourless, while some brown stones become greenish or even blue.

On account of its high refraction and great dispersive power zircon is a gem which when cut exhibits both brilliance and " fire ", and in fact approaches closer to diamond in these respects than any other stone. It is also desirable on account of its durability and the many beautiful hues in which it may be obtained. However, in spite of these desirable features, zircon has never achieved any considerable popularity.

Quartz and its varieties.—Although one of the most abundant minerals on the face of the earth, quartz in one form or another is often used for jewellery and other ornaments, but is too common to be of high value. The quartz gemstones fall into two main varieties, those which, like *rock crystal*, consist of a single individual crystal or group of macroscopic crystals, and those which, like *chalcedony* or *agate*, are made up of an aggregate of microscopic crystals. The former varieties are generally perfectly clear and transparent, while the latter are translucent or opaque.

Quartz consists of silica (SiO_2) and is a trigonal mineral forming prismatic crystals terminated, often doubly, by pyramidal planes. Its hardness is 7, specific gravity about 2·65, mean refractive index 1·55, birefringence and dispersion low, lustre vitreous and cleavage absent. Individual crystals may attain prodigious size.

Among the varieties of quartz used as semi-precious stones are *rock crystal*, which is colourless and limpid; *citrine*, which is also transparent but yellow, and often confused in the trade with " topaz "; *amethyst*, the well-known purple or violet stone; *smoky quartz* or *morion* often called " smoky topaz," which ranges from clove-brown to smoke-grey in colour, the brownish yellow variety being known as " cairngorm "; and *rose quartz*, which is pink to rose-red and generally turbid.

There are also the varieties whose special characters are due to inclusions or to a fibrous texture. These include *avanturine*, which is speckled with reddish brown flecks due to iron oxide, and *green avanturine*, with inclusions of chrome-mica (fuchsite); *cat's eye*, sometimes called *quartz cat's eye* to distinguish it from cymophane (p. 15), a milky-green or white translucent stone showing marked chatoyance; *tiger's eye*, a golden-brown, fibrous, chatoyant mineral resulting from the silicification of Cape blue asbestos, and the blue-grey variety known as *hawk's eye*; *prase*, a leek-green translucent mineral, the colour of which is due to minute acicular inclusions of actinolite; and variously named kinds containing needle-like inclusions of rutile, hornblende, manganite, gœthite or other minerals.

The compact or microcrystalline varieties of quartz used as gems are also very popular. *Chalcedony* is the general name for the group, all of which have a finely fibrous structure and are somewhat porous so that they lend themselves to artificial staining. In a restricted sense the term chalcedony applies only to those varieties of uniform pale tint, mainly white or pale grey, yellow, etc., the names *carnelian* and *plasma* being applied to red and green shades respectively. *Sard* is an orange-brown carnelian, and *heliotrope* or " blood-stone " a kind of plasma with blood-red spots or patches. *Agate*, perhaps the most popular of these stones, is built up of narrow layers of chalcedony of different transparency or colour, often arranged concentrically, which appear as bands when cut. *Onyx* is a variety of agate in which black and white bands alternate, while *sardonyx* has red and white bands. Varieties of quartz which are microcrystalline but granular include *chrysoprase*, an apple-green translucent stone with rough splintery fracture, and *jasper*, which is always opaque, has an even conchoidal fracture and although generally red or red-brown may be of many other colours.

Quartz gemstones are used not only in rings and necklaces, but also as ornamental stones in pieces of considerable size for mosaics, seals, boxes, etc., while the banded agates, especially onyx and sardonyx, are particularly suitable for the cutting of cameos and intaglios. Rock crystal is used for optical lenses and spheres for crystal-gazing as well as for piezo-electric purposes in connection with wireless telephony. As a gem it is greatly lacking in brilliance and fire, but much superior in durability to " paste." Amethyst, at one time in great demand, is no longer in vogue. Chrysoprase is now probably the most esteemed variety of quartz.

Peridot.—To the mineralogist peridot is known as *olivine*, which is a silicate of magnesium and iron, but demantoid garnet is miscalled " olivine " by jewellers. Peridot of gem quality is a transparent bottle-green or olive-green stone, sometimes called " the evening emerald." The crystals are usually flattened prisms of the orthorhombic system with a hardness of only $6\frac{1}{2}$ to 7, specific gravity 3·3 to 3·5, mean refractive index about 1·68, strong birefringence, and weak dichroism. *Chrysolite* is a greenish yellow variety of peridot, when the term is used in its strict sense.

Chrysoberyl and alexandrite.—The mineral *chrysoberyl* is an aluminate of beryllium, tinted by traces of oxides of iron and chromium. The crystals are usually complex twins, which, although orthorhombic, simulate hexagonal symmetry. The hardness is $8\frac{1}{2}$, specific gravity 3·7 to 3·8, mean refractive index 1·75, and birefringence low.

The commonest colour is greenish yellow, and such stones were formerly included under the term "chrysolite" (which is also applied to peridot), but the most remarkable variety is the bluish-green to dark green stone called *alexandrite*, which in artificial light appears raspberry-red. The dichroism of this stone is most exceptional and the striking contrasts in colour which appear when the stone is turned make it unique among gemstones.

Cymophane is a finely fibrous variety of chrysoberyl which exhibits marked chatoyance, and is called *cat's eye* (or true cat's eye to distinguish it from quartz cat's eye). Chrysoberyl, although very durable, is not used very much in jewellery.

Lapis lazuli.—Lapis lazuli or *lazurite* has been used as an ornament from very ancient times, especially for beads and mosaics. It is opaque with a deep blue colour and granular structure, having hardness 5½ and specific gravity about 2·4. It is a substance of complex composition, being essentially a sulpho- and chloro-silicate of sodium, calcium and aluminium, but contains some other minerals, which are often apparent as black and white streaks and patches with flecks of iron-pyrites. The blue ingredient is used as a pigment under the name ultramarine.

Similar in appearance is *lazulite*, which, however, has a different composition, being a basic phosphate of iron, magnesium and aluminium. The colour is azure blue and the specific gravity about 3·1.

"Swiss" or "German" lapis is the name applied to jasper which has been artificially stained blue to imitate the true stone.

Felspar gemstones.—A number of semi-precious stones of minor importance belong to the felspar group of minerals, which are alumino-silicates of the alkali metals or calcium. Their crystal forms and optical properties vary rather widely, but those used as gems are practically all translucent to opaque. Their hardness is inferior (about 6), and their specific gravity from 2·5 to 2·7.

Moonstone, which is frequently used in rings, is a milky and opalescent variety of the potash felspar *orthoclase*. A transparent yellow variety of felspar comes from Madagascar. *Amazon-stone* is an apple-green variety of *microcline* which remotely resembles jade. *Sunstone* or *avanturine felspar* is a reddish variety of *oligoclase* with included copper-coloured spangles of iron oxide.

Labradorite is a soda-lime felspar, ornamental varieties of which often show a decided play of colours, but the name is also applied, especially in Russia, to the anorthosite variety of gabbro, a rock composed mainly of plagioclase felspar, used for ornamental purposes.

Kunzite and hiddenite.—These gemstones are varieties of *spodumene*, which is a silicate of lithium and aluminium crystallizing in the monoclinic system as prisms or tabular masses. The hardness lies between 6 and 7 and the specific gravity between 3·1 and 3·2, the mean refractive index being 1·66 and double refraction strong. *Kunzite* is pale pink or lilac in colour, and often forms large crystals, while *hiddenite* is yellow- to emerald-green and the crystals are small. Both are transparent and dichroic. These gem stones, which only came into use in the 19th century, have achieved more popularity in the United States than elsewhere.

Among gem-dealers the name *spodumene* is usually applied only to the colourless or yellow varieties of this stone.

Pearl.—Although their collection can hardly be regarded as a branch of the mineral industry, pearls figure conspicuously as gemstones and are therefore briefly mentioned here for the sake of completeness.

Pearls are found in the shells of certain oysters and mussels and have been formed by the mollusc depositing a secretion of carbonate of lime around some irritant particle or parasite which has entered the shell. They are built up of layers of aragonite and a horny substance, and have a hardness of 2½ to 3½ and a specific gravity of 2·5 to 2·7. They are translucent to opaque with a characteristic lustre, and although usually yellowish-white or bluish-white, they may be pink, yellow, green, black, brown and many other colours. Those with a rosy sheen are considered the most valuable.

Pearls may be either embedded in the mantle of the oyster or attached to the shell, but the former being spherical or pear-shaped are by far the most valuable. Irregularly shaped or *baroque* pearls are less valuable than regular ones.

Unlike other precious stones, pearls are neither cut nor polished, but have only to be drilled to be ready for use in jewellery. Occasionally they are artificially bleached to improve the colour.

Because of their softness and the ease with which they may be spoiled by contact with exudations from the skin, pearls are perhaps the least durable of precious stones and must be treated with great care. They have a tendency to deteriorate with age owing to the decay of the organic matter of which they are partly composed. Their high value is due to the great rarity of the finest specimens, which makes them by far the most valuable of all precious stones.

The principal pearl-fisheries are in the Persian Gulf, the Red Sea, and off the coasts of Ceylon, India, Japan, Venezuela, Panama, Australia and many of the Pacific Islands. In recent years the finest pearls have come from the Persian Gulf, while the coast of Venezuela provides most of the valuable black pearls. A few fine freshwater pearls have been obtained from mussels taken from Scottish and Welsh rivers.

Since the war, a considerable industry in artificially-produced real pearls has grown up. These, which are known as *cultured pearls*, are produced by introducing a foreign body into the shell of a live oyster so as to induce it to deposit the pearly secretion around the irritant. It is an old practice carried out on modern scientific lines by the Japanese.

Pearls have for many years been imitated in glass, coated with a preparation obtained from fish scales.

Among the many other minerals occasionally used as gemstones a few call for special comment.

Cordierite or *iolite*, which resembles sapphire and is sometimes known as " dichroite " or " water-sapphire," is a blue or violet stone exhibiting extreme dichroism, from greyish-white to deep blue. Hardness is 7 to $7\frac{1}{2}$ and specific gravity about 2·6. The mineral is often full of flaws and rather opaque.

Benitoite, a silicate of barium and titanium, is also deep blue, resembling sapphire. Hardness is $6\frac{1}{2}$, specific gravity 3·65, refractive index high, double refraction and dichroism strong. *Euclase* is a rare beryllium-aluminium silicate resembling aquamarine; *phenakite*, a beryllium silicate, is colourless, yellowish or rose-red and resembles quartz, while *beryllonite*, a beryllium-sodium phosphate, is colourless to pale yellow. *Andalusite*, a silicate of aluminium, is sometimes transparent and suitable for cutting. It is markedly dichroic and may appear reddish or pale amber-brown in one direction and light bottle-green in another. Its hardness is above 7 and specific gravity 3·18. *Kyanite*, a mineral of similar composition, is very seldom used for gem purposes. *Sphene* and *axinite* are other strongly dichroic minerals rarely used as gems. *Iron-pyrites* and *haematite* are sometimes used in jewellery, both being often known as " marcasite."

Included among semi-precious stones are some used more for large ornaments than for gem purposes.

Fluorspar is an abundant mineral which is sometimes carved into vases, ornaments and beads. It is soft and transparent and may be of almost any colour, violet, blue, green and yellow being the commoner shades. It crystallizes in cubes and octahedra or may be massive, with hardness 4, specific gravity 3·2 and refractive index 1·433. Besides being soft, fluorspar is brittle and has very perfect cleavages in four directions parallel to the octahedron faces. It consists essentially of calcium fluoride, and is also used in metallurgical processes and for optical lenses.

Malachite and *azurite* are basic carbonates of copper, the former being emerald-green and the latter azure-blue. Both are soft and usually opaque with specific gravity 3·7 to 4·0. Malachite, which is more commonly used, often occurs in nodular masses which when cut display a banded structure. *Rhodonite*, a silicate of manganese, has a hardness of 6 and a specific gravity of 3·6. It possesses a fine red colour and is sometimes quarried as an ornamental stone. It is also an ore of manganese.

Steatite or *soapstone*, *meerschaum* and *serpentine* are soft minerals sometimes used for ornaments.

A few substances of organic origin have been used to some extent for the same purposes as gemstones. They include amber, jet and coral.

Amber.—Amber is a fossil resin derived from extinct coniferous trees, and varies in colour from yellowish-white to reddish-brown, the usual colour being honey-yellow; it may be clear and transparent or cloudy and translucent, and sometimes exhibits a greenish fluorescence, like oil.

Amber is amorphous and isotropic, with refractive index about 1·54, specific gravity about 1·1 and hardness 2 to 2½; it is brittle and breaks with conchoidal fracture. When rubbed with a cloth amber acquires a negative electric charge and will readily attract and pick up small pieces of paper; it is also a bad conductor of heat and therefore does not feel cold to the touch. Occasionally pieces of amber enclose plant remains, insects, hair, etc., many of which represent extinct species.

The chief source of amber is the north-west coast of Samland, near Königsberg, in East Prussia, where it occurs in glauconitic sands and clays of Lower Oligocene age. It also occurs in similar beds in many other parts of Germany as well as in Lithuania, Latvia and the other countries bordering on the Baltic Sea. Other countries where amber is obtained include Sicily, Rumania and Holland, while a very dark variety known as *burmite* comes from Burma. A few pieces of amber are sometimes picked up on the east coast of England, and there are occurrences in Canada.

Natural amber is found in the form of rounded lumps and is known as *block amber.* Chippings and otherwise waste material are softened by heat and then pressed into solid blocks of reconstructed amber known as *amberoid;* this material frequently passes for natural block amber.

Amber was probably one of the earliest materials used for personal adornment on account of the ease with which it can be cut and carved, and many fine examples of artistic pieces carved long ago are still extant. Although still used for beads and other ornaments as well as for pipes and cigarette-holders, amber has been largely replaced for these purposes by synthetic resin substitutes, some of which are very difficult to distinguish from true amber.

Besides its limited use as an ornament, amber is employed in certain varnishes.

Jet.—This is a variety of coal, a dense black lignite, capable of taking a fine polish. It varies in hardness from 3 to 4, and has a specific gravity of 1·35.

Formerly in considerable vogue for mourning jewellery, jet is not much used at the present time as fashion has changed. The centre of the jet-ornament industry was Whitby in Yorkshire, where towards the end of last century, the annual value of the trade reached nearly £100,000. It has now declined, and the local carvers produce ornaments mainly for sale to tourists.

Coral.—Coral, the axial skeleton of the coral organism, consists principally of calcium carbonate with some magnesium carbonate and a little organic matter. The kind used in jewellery is that secreted by *Corallium rubrum* or *C. nobile*, which grows with a branch-like habit along the shores of the Mediterranean Sea, and is chiefly rose-pink to blood-red in colour. The colour is said to be due to iron oxide.

Marseilles was formerly the centre of the industry but Naples is its present home, and it is said that in this town several thousand persons, chiefly women, are engaged in the working of coral. There is a constant demand for coral necklaces, etc., in Middle Eastern and Eastern countries and for coral rosaries, etc., in Roman Catholic countries.

Coral is sometimes artificially dyed to improve the colour, but the result is not permanent.

MODES OF OCCURRENCE.*

Many precious stones are to be found in river gravels, for they are mainly durable minerals capable of withstanding abrasion and the effects of weathering. They are also somewhat heavy minerals and have become as a rule segregated from lighter constituents by the running water. Most of the sapphire, ruby, spinel, topaz, tourmaline, zircon and garnet, together with much of the diamond, jadeite, beryl, chrysoberyl, quartz and agate produced come from such gravels. Emerald, opal, turquoise, malachite and fluorspar are, on the other hand, obtained almost exclusively from their original sources.

The origin of diamond is somewhat obscure, for while it is obtained in large quantities in South Africa from a basic igneous rock known as kimberlite, some authorities hold that it is not an original constituent of this rock. In some Brazilian deposits, diamond may be a primary constituent of a less basic type of igneous breccia in which it occurs in commercial quantity. Cases are on record of isolated diamond crystals occurring in amygdaloidal andesite, dolerite and also in pegmatite. The primary source of most of the diamond found in alluvial deposits is quite unknown.

The primary rock from which most other gemstones are derived is pegmatite. Tourmaline, beryl, quartz, spodumene, topaz, zircon and the felspar gems especially have been derived mainly from this rock, while the emerald of Colombia most probably had a similar origin.

---

* The geologic and geographic occurrence of precious stones, by S. H. Ball; Econ. Geol., 1922, 17, 575–601.

Sapphire is derived from many different rock types, such as gneiss, schist, metamorphic limestone, basic intrusive rocks, basic lavas and pegmatite. The finest sapphire, that from Kashmir, is said to have originated in kaolinized pegmatite, while the finest ruby, which is obtained from Burma, is derived from a metamorphosed dolomitic limestone, in which it is associated with spinel. Schists and gneisses provide the source of the garnets almandine and demantoid as well as nephrite, while jadeite, some emerald, phenakite, chrysoberyl, cordierite and andalusite originate in those altered by contact with igneous rocks. Lapis lazuli occurs in contact metamorphosed limestone, olivine in basic lava and basic dykes, pyrope garnet in basic dykes, and some zircon in syenite. Opal, agate, some quartz, turquoise, chrysoprase, malachite and azurite owe their origin to aqueous deposition.

As a rule, better quality precious stones are obtained from alluvial deposits than from hard rock mining operations, because only the less flawed stones are able to survive the drastic action of the streams.

CUTTING AND POLISHING.

In order that the beauty of precious or ornamental stones may be seen to the greatest advantage, it has long been the practice of lapidaries to cut and polish them in a manner most appropriate to the stone and to the purpose for which it is to be employed. In general it may be said that the clear transparent stones lend themselves to faceting, while the opaque and translucent ones do not. The latter are most commonly ground to a rounded form known as *cabochon* which may be double convex, plano-convex or concavo-convex. The deep purple-red garnet almandine, or carbuncle, is very often cut in this manner, as are opal, star sapphire, onyx, cat's eye, and turquoise. Pearl is neither cut nor polished.

In the proportioning and shaping of a faceted stone close attention is paid to the properties of refraction and dispersion of light and of dichroism, so that where these properties are strongly marked they may be best displayed in the finished brilliant. Flaws and patches of uneven colour are also removed in the cutting.

The form of cutting largely employed for the diamond is that known as the brilliant-cut consisting of 58 facets, of which 33 are on the *crown* or upper part, and 25 on the *pavilion* or under side of the stone. The edge bounding the widest part of the stone and separating the crown from the base is known as the *girdle*, the large horizontal face at the top being known as the *table*, and the small face at the bottom, parallel to the table, the *culet*.

In a cut diamond, one-third of the total thickness should lie above the girdle, and the table should occupy four-ninths of the total breadth of the stone. If properly proportioned, practically the whole of the light entering the brilliant will be internally reflected and will emerge through the crown. Several modifications of the brilliant-cut exist, having 66, 74, 80 or even 88 facets.

In a brilliant-cut diamond the girdle approaches a circle in outline, but when sapphire, ruby and zircon are cut in this manner the girdle more often approaches a square, the facets being reduced in number and the proportions suitably altered to ensure maximum internal reflection with the lower refractive index of these stones.

Emerald, topaz and many other coloured stones are usually cut in another style called trap-cut or step-cut, which displays advantageously the colour of these stones, whose brilliance and fire is insufficient to warrant the type of cut used for diamond. Step-cut stones are rather flat and oblong, with a table and one or more sloping step facets parallel to the girdle on the upper side, and a larger number of similar facets below the girdle, diminishing in size down to the culet. Sometimes a mixture of step and brilliant cut is employed. The old-fashioned rose-cut, now only employed for very small diamonds, consists of a single flat face below and 24 triangular facets above.

The cutting of diamond is achieved in three stages. First, flaws and irregularities are removed by cleaving the stone, making use of the octahedral cleavage of diamond, by embedding it in shellac, notching it in a suitable place with another stone, inserting a dull-edged steel knife into the notch and giving this a sharp blow, when the stone parts along the cleavage plane. In fashioning a normal regular brilliant the cleaving is continued until a regular octahedron is obtained which forms the starting point for further operations.

The next operation is to saw the octahedron into two parts by means of a very thin phosphor-bronze disc, charged with diamond-dust and oil, which is rapidly rotated by power in a vertical plane, the stone being embedded in solder held in a metal cup-like holder.

Formerly it was the custom to cut off from the apex five-eighteenths of the vertical height of the octahedron, the plane so produced ultimately becoming the table of the brilliant. It is, however, less wasteful to adopt the modern method of slicing the octahedron into two equal pyramids, the square bases of which ultimately become the tables of two brilliants. By this means only 45 to 48 per cent. of the octahedron is removed in fashioning brilliants, and some of this can be employed in producing small rectangular gems called *baguettes*, the demand for which is considerable.

After shaping by the cutter, the stone is ready for the polisher who grinds and polishes the facets. The stone is held on the top of a mound of fusible alloy in a broad pear-shaped metal holder known as the *dop*. This is held by the stalk in a clamp with the stone downwards, the latter pressing against the upper surface of a circular cast iron plate or lap charged with diamond dust and oil, which revolves in a horizontal plane at about 2,500 revolutions a minute. The dop is constantly removed and cooled by plunging in cold water, four dops usually being in use on one polishing lap at the same time. The stone has to be turned and re-set many times, as not more than six facets can be polished with one setting.

It is important that the operations of sawing and faceting should be carried out " with the grain," for the hardness varies in different directions. It is, for example, much easier to grind a table face in a direction from the centre of one octahedal face to the centre of the opposite face, than from one edge to the opposite edge.

The facet being polished is invisible to the polisher, who works entirely by experience and intuition. Except for a few gauges, practically no mechanical devices are employed to aid the polisher in fixing the correct angles for the facets or to ensure that each receives the correct amount of polishing. This is therefore most highly skilled workmanship, an art which is often handed down from father to son.

Diamond cutting began in Antwerp in the 15th century and in Amsterdam about 1580, and these two cities are still by far the most important centres of the industry. In normal times probably more than 10,000 workers are employed in each of these centres, and the industry, which at one time was carried on largely in the homes of the cutters, now maintains cutting shops each of which is equipped with 200 to 800 sawing machines.

Of minor importance are the cutting establishments in Paris, New York, Germany (Hanau) and Borneo. Diamond cutting is also carried on in London where, since quite early times, many fine stones have been cut and re-cut. In recent years a determined effort has been made by the Government of the Union of South Africa to establish a large-scale cutting industry in that country, to aid which an export tax of 10 per cent. was placed on uncut stones. The future of the new industry is not yet assured, but in 1931 27 cutting establishments were operating and more than 4,000 carats of polished stones were turned out, valued at nearly £75,000.

The cutting of the other precious and semi-precious stones is carried out on similar lines, but is neither so difficult nor so tedious an operation as diamond cutting. Slitting or sawing is usually done with a thin disc of phosphor bronze or tinned iron charged with diamond powder and run at a high speed in a vertical plane. Cutting or faceting is accomplished by the aid of a copper lap or wheel charged with diamond powder, after which each facet is gone over again by another craftsman, known as a polisher, on a copper lap to which is applied a wet paste of rottenstone or tripoli. Cabochon-cut stones, such as opal, carbuncle (garnet), turquoise, etc., are usually ground on a wheel of emery or silicon carbide and polished on a wooden lap to which a thick cloth such as billiard- or box-cloth is attached and pumice powder applied. The final finish is obtained by the use of putty powder in place of pumice powder.

The principal centres for the cutting of these stones are, London and Paris for the fine precious stones, Idar and Oberstein in Germany for most of the semi-precious stones, and St. Claude (Jura) in France for the poorer qualities of precious stones and also artificial stones. Czechoslovakia is noted for the cutting of garnets and imitation or paste gems. Gem cutting is also carried out in the United States, but not on a scale which justifies its being considered an industry.

ARTIFICIAL STONES AND IMITATIONS.*

Like all valuable objects, precious stones are often imitated. This is achieved in one of four ways—(*a*) by artificial production of the mineral; the products being known in the trade as " synthetic " stones, (*b*) by substituting one stone for another, sometimes after altering the colour, (*c*) by simulating the stone in glass or other artificial product, (*d*) by employing composite stones.

A " synthetic " stone is the best substitute for the real and is the most difficult to detect.

It is very doubtful whether diamond has ever been made artificially, even in crystals of microscopic size, and the only precious stones (excluding cultured pearls) which can be manufactured with commercial success are the gem varieties of corundum and spinel.

The process is briefly as follows. Pure alumina in powder form, obtained from alum, is mixed with a suitable amount of another metallic oxide such as chromium oxide, nickel oxide, iron oxide, titanium dioxide or vanadic oxide to give the required shade of colour to the finished product. A stream of this mixture is allowed to fall into the jet of an oxy-coal-gas flame impinging on a rotating fire-clay support. A pear-shaped mass of fused alumina slowly forms, which when cool is known as a *boule*, and weighs about 30 carats. Such material when cut and polished exhibits all the properties of a natural ruby or sapphire.

An artificial stone has recently been introduced in various colours which differs in composition from any natural mineral.† It is manufactured by a process similar to that outlined above but contains about 10 per cent. of magnesia, and closely resembles spinel. " Synthetic " stones can as a rule only be distinguished by experts.

Artificial rubies and sapphires are manufactured chiefly in Germany, France, Switzerland and Italy.

---

* Die künstlichen Edelsteine, by H. Michel; 2nd edit., Leipzig, 1926, 477 pp.

† Morphologische und physikalisch-chemische Untersuchungen an synthetischen Spinellen als Beispielen unstöchiometrisch zusammengesetzter Stoffe, by F. Rinne; Neues Jahrb. Min., Abt. A, 1928, 58, 43–108. An artificia gemstone isomorphous with spinel, by P. F. Kerr; American Min., 1929, 14, 259–264.

The substitution of one stone for another, such as a jargoon for a diamond, or a garnet for a ruby, is a common trick which is frequently played upon the unwary, but one which may be readily detected by an experienced gem dealer. Sometimes, however, the detection may be more difficult as for instance where a green garnet is substituted for jade or citrine for heliodor. Porous stones such as agate and chalcedony are very frequently dyed to represent onyx, carnelian, lapis lazuli, etc., while the colour of other stones is sometimes improved by a heat treatment.

The manufacture of glass imitations of gem-stones is a well-known trade. The glass is specially made to have as high a refractive index and specific gravity as possible and is known as *paste* or *strass*. It is suitably coloured by incorporating various metallic oxides, and then cast in moulds cut to the shape required, the faces being polished and the edges sharpened by subsequent grinding. All glass substitutes are very soft and easily scratched, and all are isotropic. Their brilliance is often enhanced by a backing of silver paint or tinfoil. Gablonz in Czechoslovakia is a famous centre for the manufacture of paste imitations, which are frequently sold by jewellers under the name of " Parisian gems."

Turquoise may be imitated in enamel or in blue opal glass; jade, in green and white opal glass or in a synthetic resin of the bakelite type. The latter may also be used to imitate several natural stones, especially amber.

Composite stones are less often employed to-day than formerly. Emerald may be imitated by cementing a layer of green glass or even gelatine between two layers of beryl, or two pieces of diamond may be cemented together to form a larger stone. Again, a real stone may be backed by similarly coloured glass or even by an artificial stone. Such imitations, known as *doublets* and *triplets*, can only be detected by experts.

Opal has the advantage over all other precious stones in that it has not, so far, been imitated successfully.

MARKETING.

The discovery and rapid development of the diamond fields of the Union of South Africa, towards the end of the last century, led to a great increase in the production of diamond for gem purposes. For about 20 years the industry was uncontrolled, in consequence of which the prices realized were low, and it was at times difficult to dispose of the stones. The big producers in the Union therefore decided to market their produce through one channel.

In 1893 the London Diamond Buying Syndicate was formed, which entered into agreements with the chief diamond producers in the Union to take their output and market the stones on a profit-sharing basis, and in view of the fact that the mines are able to supply much more than the world's demands, these producers from time to time made arrangements for the strict limitation of output to an agreed figure to which each contributed a certain quota. After the war the agreements included the output of South-West Africa which was the chief competitor, but conditions were changing and whereas before the war the South African mines produced 76 per cent. of the world's output, other producers began to increase their relative proportions so that in 1920 the South African mines production had dropped to 67 per cent., in 1921 to 49 per cent., and in 1922 to 35 per cent. of the total world's production, and although it rose to 56 per cent. in 1923 and 1924, the old syndicate no longer exercised a controlling influence.

In 1925 a Diamond Control Act was passed by the South African Parliament enabling the Government to take over control of the mining and disposal of precious stones, in the absence of an approved interproducers' agreement. In order to meet the situation, a new and much more powerful syndicate came into being during 1925 which controlled the output of more producers than its predecessor, and whose financial resources were exceptionally strong. In addition to having the disposal of the output of all the important mines in the Union and of the Consolidated Diamond Mines of South-West Africa, Ltd., it controlled the sales of stones from the alluvial fields of Angola and the Belgian Congo.

The syndicate made a contract with the producers which was similar to previous arrangements but more favourable to the producer. Stones were bought at a price based on the market price for the preceding 6 months with re-adjustments at the end of each period. Losses were borne by the syndicate who took all the profits up to a certain figure, any excess being divided in an agreed proportion, and the contract ran for 5 years from January 1st, 1926. The quotas arranged between the leading producers in the Union were De Beers 51, Jagersfontein 10, Premier 18 and Consolidated Diamond Mines of South-West Africa 21 per cent. of total sales.

When the agreement terminated at the end of 1930, negotiations for a renewal were very protracted, largely owing to the unwillingness of the South African Government to submit to the control of the other producers in marketing stones from the State diggings in Namaqualand.

Eventually a new company (the Diamond Corporation) was formed, with headquarters this time in South Africa, to take over from the syndicate and the producers the accumulated stocks of unsold stones and sell them according to market requirements. It sells to cutters in lots.

A new system of quotas was not arranged until May, 1931, the arrangement being briefly as follows.* The Corporation is to buy diamonds worth not less than £1,200,000 and not more than £4,000,000 each half year, and the Government agrees voluntarily to limit its sales proportionately to other producers with a maximum of £1,500,000 for the year, reserving the right to sell direct to South African cutters a minimum of £375,000 worth each year, but to maintain prices and qualities as arranged by the Corporation and thereby avoid unfair competition. The new quota percentages are Jagersfontein 10, Premier 10·6, Consolidated Diamond Mines of South-West Africa 25, De Beers 54.

In addition to those producers who have agreed to sell through the Corporation, a number of the outside producers find it convenient to dispose of much of their output through this channel.

In spite of rigid surveillance a few fine stones and many of moderate value are constantly smuggled from the producing fields in various countries.

The principal markets for other precious stones are in London, Paris and New York. Agate and the semi-precious stones find their chief market at Idar in Germany, where there is a large cutting industry. Jadeite is sold at markets near the Burmese mines and at Canton.

PRICES.

Precious and semi-precious stones are sold by weight, but unlike most other minerals, the value of a precious stone is quite independent of the cost of production. It depends primarily on rarity and then on size, colour, brilliancy, cleanness, and, especially with the smaller stones, on the demand at the moment. The price is also considerably influenced by the skill with which a stone has been cut, and it is quite a common practice to recut a large but poorly-cut stone and thereby increase the value in spite of decreasing the weight.

In the case of diamond, the price is artificially controlled to a large extent by the big producing companies selling through a single channel and limiting production.

J. R. Sutton has recently suggested a formula for calculating the value of a rough diamond based on an analysis of price lists drawn up by the mining companies.† His formula is

* The Mineral Industry, 1930; Precious and semi-precious stones, by G. F. Kunz, p. 511.

† Diamond, by J. R. Sutton; London, 1928, p. 113.

$(n-1)D + P = R$, where D is approximately the difference in price between crystals of one and two carats, P is the price of a stone of one carat, n is the weight of the stone, and R is the total value of the stone. He cites a number of examples to show how closely this formula corresponds with the actual prices realised by stones of a wide range of sizes and grades from the Bultfontein and Wesselton mines.

The prices of diamond and other valuable stones rapidly rise with increasing weight, and while it is impossible to give details of all grades and sizes, the following table indicates the prices of cut stones in London in June, 1933 :—

Stone.	Quality.	Value per carat.			
		1 carat.	2 carats.	3 carats.	4 carats to 8 carats.
Diamond	Medium	£25–30	£40–45	£50–55	£60–80
	Fine	£50	£65	£85	£100–250
Emerald	Medium	£30	£50	£70	£125–250
	Fine	£80	£200	£250	£350–1,000
Ruby	Medium	£10	£20	£40	£70–250
	Fine	£30	£50	£100	£200–1,000
Star ruby ...	Medium	20*s*.	£3	£5	£8–20
	Fine	£2	£5	£10	£25–50
Sapphire	Medium	£5	£8	£10	£15–35
	Fine	£12	£20	£25	£35–80
Star sapphire ...	Medium	10*s*.	15*s*.	20*s*.	£2–4
	Fine	20*s*.	30*s*.	£2	£6–12
Black opal... ...	Medium	10*s*.	20*s*.	£2	£3–5
	Fine	£2	£3	£6	£8–15
White opal ...	Medium	8*s*.	12*s*.	20*s*.	£1–2
	Fine	15*s*.	30*s*.	£2	£2–4
Chrysoberyl	Medium	10*s*.	15*s*.	25*s*.	£3–5
(Cat's eye).	Fine	20*s*.	30*s*.	£3	£7–20
Alexandrite ...	Medium	£2	£3	£5	£6–10
	Fine	£4	£6	£10	£10–30

The following list shows the approximate prices of some of the less valuable stones.

	Price (shillings per carat).		*Price* (shillings per carat).
Spinel	5 to 100	Zircon	2 to 40
Demantoid ("Olivine").	10 to 100	Tourmaline	5 to 30
		Peridot	3 to 20
Garnet	2 to 5	Amethyst	2 to 10
Brazilian topaz ...	10 to 80	Turquoise	1 to 10
Aquamarine	5 to 60	Citrine ("Quartz topaz").	1 to 3
Pink beryl	5 to 60		
		Moonstone	½ to 6

All the above prices were kindly supplied by Chas. Mathews, Esq., F.G.S., Hatton Garden, London.

WORLD'S PRODUCTION.

Apart from diamond, the statistics available for the production of precious stones are scanty and unreliable, and even the figures for diamond are incomplete. It is therefore impracticable to compile a table of world production for precious stones in general, but one restricted to diamond appears on pages 30-31.

S. H. Ball* has compiled a table, based largely on pre-war data, showing the presumed value of the world production of all gemstones (other than pearl) in the rough " in normal years ". No great accuracy is claimed for the compilation, but it brings out, to some extent, the relative importance of the different stones.

The presumed annual value of all gemstones is about £16½ million, of which diamond accounts for 94·3 per cent., while sapphire, emerald, ruby, jadeite, turquoise and opal together make up 3·6 per cent. Amber accounts for about 1 per cent., leaving only 1 per cent. for the remainder.

As regards diamond, South Africa has for many years dominated the situation, but in recent years this domination has become much less marked owing to the greatly increased production of low-grade stones in the Belgian Congo, the Gold Coast and other alluvial fields in Africa. In the matter of value, however, the South African output still greatly exceeds the total of all other countries as it is this diamond which is chiefly used for gem purposes.

Owing to the financial depression of 1930 and subsequent years the sales of diamond in South Africa fell so far below the production that great restrictions had to be put upon output and many mines have been shut down, at least for the time being.

The statistics of output recorded by countries take no account of grade, diamond used for industrial purposes being included with that which is of gem quality and size, but the industrial stones make up a much larger proportion of the total caratage than is generally imagined. A few years ago it was estimated that about 40 per cent. of the total quantity of diamond produced was used for industrial purposes, but in view of the recent increases in production of this class of material from Central and West Africa, and the decrease in production of gem diamond in South and South-West Africa, it seems very probable that the proportion used industrially is now even greater.

Statistical information concerning other stones will be given in this publication where possible in the section which deals with their occurrence in the several countries.

---

* *Op. cit.*

The following list shows the principal countries in which most of the world's gemstones are produced or mainly occur.

Sapphire.—Ceylon, India, Siam, Indo-China, Australia.
Ruby.—India, Ceylon, Siam.
Opal.—Australia, Mexico.
Emerald.—Colombia, South Africa, Russia.
Turquoise.—Persia, United States, Egypt, Russia.
Jadeite.—India.
Nephrite.—China, Russia, New Zealand.
Tourmaline.—United States, Madagascar, Russia, Brazil, South-West Africa.
Topaz.—Brazil, Russia, Japan, Southern Rhodesia.
Beryl.—Brazil, Madagascar, South-West Africa, South Africa, United States, India, Russia.
Chrysoberyl.—Ceylon, India, Russia, Brazil, Southern Rhodesia.
Spinel.—Ceylon, India, Siam, Afghanistan.
Lapis lazuli.—Afghanistan, Russia, Chile.
Zircon.—Ceylon, Siam, Australia.
Quartz, etc.—Brazil, Madagascar, Japan, Uruguay, Russia, Ceylon, South-West Africa, China, etc.
Agate, etc.—Uruguay, United States, India, Madagascar, Canada, China.
Garnet.—Czechoslovakia, Ceylon, South Africa, India, Tanganyika.
Felspar gems.—Ceylon, United States, Russia, Madagascar, Canada.
Spodumene.—Brazil, United States, Madagascar.
Malachite.—Russia, Rhodesia, United States, Belgian Congo.

World's Production of Diamond.

Quantity (Metric carats).

Producing Country.	1913.	1920.	1921.	1922.	1923.	1924.
British Empire.						
Gold Coast	—	215	1,789	6,535	23,342	53,035
Sierra Leone	—	—	—	—	—	—
Southern Rhodesia ...	998	249	141	256	543	596
South-West Africa ...	[(c) *1,570,000*]	606,424	171,321	144,156	433,229	492,696
Tanganyika Territory	—	—	—	—	—	—
Union of South Africa	5,300,484	2,612,511	828,036	669,559	2,053,095	2,440,398
British Guiana ...	(c)11,414	40,407	105,325	167,985	220,162	190,508
India (Central) ...	116	85	126	171	115	66
Australia	5,573	3,523	1,563	1,000	175	284
Total	5,319,000	3,263,000	1,108,000	990,000	2,731,000	3,178,000
Foreign Countries.						
Angola	—	93,529	106,719	98,684	94,478	118,016
Belgian Congo ...	(g)15,000	225,450	173,936	250,292	414,954	548,274
French Equatorial Africa.	—	—	—	—	—	—
Brazil	(f)	(f)	(f)	(f)	(f)	(f)
Netherlands East Indies.	(a)	421	1,817	2,000	1,169	358
Total (excluding Brazil).	(h)1,585,000	319,000	282,000	351,000	511,000	667,000
WORLD'S TOTAL ... (excluding Brazil).	6,900,000	3,580,000	1,390,000	1,340,000	3,240,000	3,850,000

Value (£).

Producing Country.	1913.	1920.	1921.	1922.	1923.	1924.
British Empire.						
Gold Coast	—	764	4,476	7,949	26,494	59,668
Southern Rhodesia ...	7,781	1,917	721	1,643	3,207	3,322
South-West Africa(d)	(c)3,297,785	4,204,338	694,107	383,239	1,446,985	1,340,872
Tanganyika Territory	—	—	—	—	—	—
Union of South Africa	11,389,807	14,762,899	3,103,448	2,266,631	6,038,207	8,033,406
British Guiana ...	(c)21,179	281,536	329,847	825,285	1,033,014	858,323
India (Central) ...	1,791	4,125	4,865	6,110	3,100	1,985
Australia	5,141	6,282	1,915	1,300	230	498
Total	11,400,000	19,300,000	4,100,000	3,500,000	8,600,000	10,300,000
Foreign Countries.						
Angola	—	(g)300,000	320,279	308,197	286,012	342,786
Belgian Congo ...	(g)15,000	(e)584,950	(e)384,740	(e)550,560	(e)617,170	(e)398,950
French Equatorial Africa.	—	—	—	—	—	—
Brazil	(f)	(f)	(f)	(f)	(f)	(f)
Netherlands East Indies.	(a)	4,587	15,525	14,370	6,412	1,906
Total (excluding Brazil).	(h)3,300,000	900,000	721,000	873,000	910,000	744,000
WORLD'S TOTAL ... (excluding Brazil).	14,700,000	20,200,000	4,800,000	4,400,000	9,500,000	11,000,000

(a) Information not available.
(b) Exports.
(c) Year ended March 31st following.
(d) Estimate based on sales values.

World's Production of Diamond—continued.

Quantity (Metric carats).

1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.
(*b*)77,313	(*b*)299,835	(*b*)460,959	(*b*)698,826	(*b*)660,536	(*b*)861,119	(*b*)880,479	(*b*)842,297
—	—	—	—	—	—	—	748
189	106	126	54	232	19	9	—
515,860	683,801	723,877	503,142	597,189	415,047	71,532	17,944
411	6,695	18,766	24,749	24,432	12,295	7,658	1,387
2,430,128	3,217,967	4,708,038	4,372,857	3,661,212	3,163,591	2,119,156	798,382
187,746	168,510	178,406	135,996	125,799	110,042	63,479	61,780
48	69	113	824	1,628	1,321	639	1,254
210	64	199	28	119	667	725	251
3,212,000	4,377,000	6,090,000	5,736,000	5,071,000	4,564,000	3,144,000	1,724,000
126,338	154,369	200,809	237,511	311,903	329,824	351,495	367,334
883,903	1,114,384	1,041,544	1,647,700	1,907,765	2,518,100	3,528,379	3,872,171
—	—	—	—	—	34	1,260	1,644
(*f*) 685	(*f*) 284	(*f*) 257	(*f*) 242	(*f*) 585	(*f*) 459	(*f*) 294	(*f*) 274
1,011,000	1,269,000	1,243,000	1,885,000	2,220,000	2,848,000	3,881,000	4,241,000
4,220,000	5,650,000	7,330,000	7,620,000	7,290,000	7,410,000	7,030,000	5,970,000

Value (£)

(*b*)98,760	(*b*)362,833	(*b*)512,159	(*b*)584,279	(*b*)584,613	(*b*)658,994	(*b*)440,924	(*b*)536,946
1,152	551	644	285	1,065	58	30	—
1,457,820	1,929,003	2,032,285	1,238,987	1,812,170	1,241,544	208,081	85,503
(*a*)	37,480	101,480	100,128	89,399	25,525	9,701	1,859
8,198,128	10,683,597	12,392,308	16,677,772	10,590,113	8,340,719	4,182,523	1,679,600
819,816	718,183	724,153	523,007	471,746	323,836	105,257	118,865
1,098	2,131	3,354	4,887	9,485	5,373	2,569	(*a*)
240	77	227	60	148	714	694	252
10,600,000	13,700,000	15,800,000	19,100,000	13,800,000	10,600,000	5,000,000	2,400,000
378,913	449,987	423,867	492,282	700,000	600,000	520,000	500,000
(*e*)607,790	(*e*)503,930	(*e*)614,130	(*e*)646,350	633,080	523,240	471,400	(*a*)
—	—	—	—	—	(*a*)	(*a*)	(*a*)
(*f*) 4,315	(*f*) 1,646	(*f*) 2,064	(*f*) 1,666	(*f*) 3,036	(*f*) 1,673	(*f*) 1,663	(*f*) (*a*)
991,000	856,000	1,040,000	1,140,000	1,336,000	1,125,000	993,000	(*a*)
11,600,000	14,600,000	16,800,000	20,200,000	15,100,000	11,700,000	6,000,000	(*a*)

(*e*) Estimate based on export values.
(*f*) Data available incomplete (see p. 109).
(*g*) Estimated.
(*h*) Chiefly German S.W. Africa.

GEMSTONES IN THE BRITISH EMPIRE.

British Isles.

Both *topaz* and *beryl* have been obtained from the granite of the Mourne Mountains in Co. Down, especially from the N.W. side of the small lake on Bingian, on Slieve Havila and on the Chimney Rock Hill. Beryl has also been found near Killiney and elsewhere in Co. Dublin.

Water-clear crystals of *rock crystal* have been obtained in a few localities, notably from quartz veins in slate at Tintagel and Delabole in Cornwall. Cut stones have been known as "Cornish" or "Bristol diamonds." Cairngorm, on the borders of Banffshire and Inverness-shire, was at one time famous for its yellowish-brown *smoky quartz* which was recovered from the débris of the weathered granite. *Amethyst* has been obtained from Cornwall and from Cork and Achill island in Co. Mayo, while *citrine* has been found in crevices in granite on Goatfell in Arran. *Avanturine quartz* is known to occur in Glen Fernate in Scotland, and *agate, jasper* and *heliotrope* at several localities also in that country; agate (known as "Scotch pebbles") at Montrose, and heliotrope especially in the basalt of the island of Rum.

The well-known "Blue John" from Castleton, Derbyshire, is a deep violet-blue *fluorspar*, often in concentric layers of different shades, which was at one time much used for carving into ornaments, but is now exhausted.

Haematite suitable for cutting has occasionally been obtained from the iron mines of Cumberland and from Scotland. It is known as "pencil ore."

Jet has been worked in the Upper Lias shales of the Yorkshire coast near Whitby and in several of the dales in the vicinity where it occurs in small flattened lenticles. It is of fine quality and was formerly in great demand for mourning jewellery, so that the winning, cutting and polishing of jet was a considerable industry in Whitby in the last century. The public taste has now changed and the industry is now quite small; practically no local material is produced and the little that is cut is imported in the rough from Spain.

Only a very small proportion of the imports of diamond is declared to the Customs on entry into the United Kingdom and included in the trade returns.

The following composite table includes exports to the United Kingdom as recorded in the trade returns of the several countries marked (*a*), together with the figures recorded in the United Kingdom returns marked (*b*). The totals are probably very incomplete.

United Kingdom.—Imports of Diamond in the rough.

Imported from	1928.	1929.	1930.	1931.	1932.
Gold Coast (*a*)					
Quantity (carats) ...	698,826	660,536	861,119	880,479	842,297
Value ... ... (£)	*584,279*	*584,613*	*658,994*	*440,924*	*536,946*
South-West Africa Territory (*a*)					
Quantity (carats) ...	503,143	597,059	414,947	71,532	17,946
Value ... ... (£)	*1,215,820*	*1,563,805*	*1,184,217*	*226,720*	*85,440*
Union of South Africa (*a*)					
Quantity (carats) ...	2,827,280	1,983,786	1,072,145	1,436,108	489,380
Value ... ... (£)	*6,717,695*	*8,117,670*	*2,766,370*	*2,076,870*	*648,798*
British Guiana (*a*)					
Quantity (carats) ...	43,172	72,56	50,603	22,876	24,555
Value ... ... (£)	*126,394*	*244,097*	*133,624*	*41,311*	*47,598*
Other British Empire (*b*)					
Quantity (carats) ...	—	1,500	—	—	
Value ... ... (£)	—	*4,500*	—	—	
Brazil (*b*)					
Quantity (carats) ...	24,589	20,397	14,846	1,888	3,975
Value ... ... (£)	*138,243*	*156,384*	*75,613*	*3,295*	(*c*)
Other Foreign Countries (*b*)					
Quantity (carats) ...	30	35	—	—	
Value ... ... (£)	*2,196*	*136*	—	—	
Total					
Quantity (carats) ...	4,097,040	3,335,878	2,413,660	2,412,883	1,378,153
Value ... ... (£)	*8,784,627*	*10,731,205*	*4,818,818*	*2,789,120*	(*c*)

(*a*) and (*b*). See note preceding table. (*c*) Information not available.

Gold Coast.*

The original discovery of alluvial *diamond* in the Gold Coast was made by Sir Albert Kitson (then Director of the Geological Survey) early in 1919 at Abomoso near the Birim river in Akim Abuakwa. Subsequent prospecting showed that diamond is widely distributed in the Birim valley and led to the discovery of extensive deposits of rich diamantiferous gravels in the district around Akwatia, which is 5 miles S.E. of Kade, the railhead of the Central Province Railway, and some 20 miles S.S.W. of the site of the original discovery. Other deposits of alluvial diamond, none of which is being worked, occur near the lower Birim and the Pra rivers, and in the vicinity of the motor road between Simpa and Tarkwa, while isolated stones have been found by the Geological Survey and prospectors in many other parts of the Colony and Ashanti.

*** Annual Repts. on the Geological Survey Dept., Gold Coast. Diamond mining on the Gold Coast, by S. V. Griffith; Mining Mag., 1929, 41, 271–281.**

A recent investigation by the Geological Survey* has demonstrated that the rocks in the vicinity of the diamond workings belong to the Birrimian System of pre-Cambrian age, and are composed largely of metamorphosed tuffaceous sandstones (greywacke) and basic lavas and pyroclastic rocks, with subordinate carbon-bearing slates and phyllites. These rocks are intruded to the south by a bathylith of granite which extends to within five miles of the workings near Kokotintin. A few dykes of amphibolite and one of dolerite were noted, but no indications of the existence of kimberlite pipes, pegmatites, or ancient conglomerates, from which the diamond could have been derived, were found in the vicinity of the mines.

The quartz fragments in the diamantiferous gravels and the heavy minerals in the concentrates (mainly staurolite and ilmenite, with some rutile, leucoxene, tourmaline, and a little zircon, haematite and magnetite) are sharply angular, and have been derived from the local rocks. The diamond is also believed to be of local origin and to have come from belts of metamorphosed basic igneous and fragmental rocks containing inclusions of carbon-bearing phyllite. In a stream near Akwatia diamond crystals with encrustations of quartz have been found.

At one of the mines the diamantiferous ground, which consists of angular quartz fragments embedded in a clayey matrix, is about 5 feet thick and rests on decomposed bedrock. It is excavated by pick and shovel and transported by truck or wheelbarrow to the washing plant. Here it is washed and sized, then concentrated in an 8-foot pan fitted with revolving arms carrying knives. The concentrate is drawn off and treated in Harz jigs. Magnetic minerals are subsequently removed with an electromagnet and the final concentrate is hand-picked for diamond.

The stones obtained are on the average very small, and although the total output to the end of 1932 was nearly 5 million carats, the largest recorded stone weighed less than 3 carats. The average size of the diamond crystals recovered is about 20 to the carat, and they are mainly employed for industrial purposes and in the "small" jewellery trade.

The commercial exploitation of the deposits commenced in 1920 and there are now two companies working on a considerable scale near Akwatia and Manso, and two others on a smaller scale near Topiramang and Kade, all in the Birim valley. The diamond output has advanced by leaps and bounds since the industry commenced, and the Gold Coast now takes a prominent place among the producing countries.

*** Information supplied by Dr. N. R. Junner, Director of the Gold Coast Geological Survey.**

Gold Coast.—Exports of Diamond (Domestic Produce).

Year.	Quantity carats.	Value £
1928	698,826	584,279
1929	660,536	584,613
1930	861,119	658,994
1931	880,479	440,924
1932	842,297	536,946

Sierra Leone.*

Early in 1930, officers of the Geological Survey found two small crystals of *diamond* in quartz gravel on the bank of the Gbobora river at Fotingaia, 6½ miles N.N.W. of Jaima in the Kono district, and there was a find near Kennema in 1931.

The country in the vicinity of these discoveries has been prospected by Consolidated African Selection Trust with encouraging results. The stones recovered are said to have been larger and more valuable than those from the Gold Coast.

The exports of diamond from Sierra Leone in 1932 amounted to only 748 carats, but during the first six months of 1933 the exports amounted to 8,586 carats.

A brilliant green chrome-iron *garnet* occurs in altered ultrabasic rocks in the Kambui hills near Kennema and Lago, Kennema district.

Small fragments of *ruby* and small *zircon* crystals of various colours are met with in some of the stream gravels.

Southern Rhodesia.†

Diamond.—Six bodies of kimberlite are known and have been examined for diamond in the Bembesi and Shangani valleys near Lochard. The rock fills fissures, in some cases enlarged by volcanic outbursts, and is oxidised to "yellow-ground" at the surface. Only two of the bodies contain diamond, the few stones found being of good quality but small and not in payable quantities.

Alluvial diamond was discovered in the Somabula forest west of Gwelo in 1903. The stones occur in a gravelly deposit of Upper Karroo age which rests on granite and extends north-west from Willoughby's Siding along the divide between the Gwelo and Shangani basins; they are also found in a superficial agate-bearing rubble.

---

* Information kindly supplied by Dr. N. R. Junner, Director, Geol. Survey, Gold Coast.

† Rept. Director Geol. Survey S. Rhodesia for the year 1915 (1916), pp. 2-5. Somabula diamond fields of Rhodesia, by F. P. Mennell; Geol. Mag., 1906, 3, 459–462. The diamond fields of Southern Africa, by P. A. Wagner; Johannesburg, 1914. The geology of the diamond-bearing gravels of the Somabula forest, by A. M. Macgregor with notes by the late A. E. V. Zealley; S. Rhodesia, Geol. Surv. Bull. No. 8, 1921.

The gravels are a series of fluviatile and estuarine deposits characterized by very well-rounded pebbles with a " wash " at the base carrying an abundance of heavy minerals, especially staurolite, with garnet, tourmaline, kyanite, rutile, topaz, corundum (including ruby and sapphire), beryl, chrysoberyl and diamond. The usual associates of diamond, ilmenite, enstatite, diopside and zircon are almost entirely absent. It appears that the deposits were brought down by rivers from the north, and that they formerly had a much wider extent than at present, but there is little or no evidence to show their original source.

The stones themselves are mostly characterized by a greenish tinge which is lost on cutting, but colourless and yellowish-brown ones are found, and the fact that stones of the same colour appear to have become segregated in the deposit tends to suggest that the coloration is due to secondary changes. It has been ascribed by Mennell to some influence of the matrix in which the stones are embedded,* and by Wagner to radio-activity.†

The deposits were exploited on a large scale by a company formed for the purpose, but the amount of diamond recovered was insufficient to pay expenses and operations ceased in 1908. The ground was then thrown open to individual diggers, and is still being worked in this way. The main diggings are situated near Willoughby's Siding and on Ngamo farm along the north-western edge of the deposit. The peak of production was reached in 1916 with 1,021 carats, but since then there has been a steady decline, no new deposits and no rich pockets having come to light for some time. The annual production in recent years has been negligible.

The method of working the gravels and recovering the stones is similar to that employed in the Union of South Africa.

Of the other gemstones mentioned above as occurring with the diamond in the Somabula field only *chrysoberyl* and *topaz* are of economic importance. The chrysoberyl is of deep yellow colour and stones of one carat and more fetch 2s. 6d. per carat in the field. The topaz, which is more valuable, is of a blue colour and almost as rare in the deposits as the diamond.

South-West Africa Territory.‡

Diamond. In the Gibeon, Bethany, Berseba and Maltahöhe districts of South-West Africa, some forty or more pipes and dykes

* Note on the colours of some alluvial diamonds, by P. A. Mennell; Min. Mag., 1915, 17, 202–204.

† Proc. Geol. Soc. S. Afr., 1917, 20, xxvii-xxx, Pres. Address by P. A. Wagner.

‡ Ann. Repts. on administration of S.W. Africa. Diamond fields of German South-West Afr., by C. W. Boise; Mining Mag., 1915, 12, 329–340. The geology and mineral industry of South-West Africa, by P. A. Wagner; Geol. Surv. Union of S. Afr., Mem. 7, 1916. Minerals and mines in South-West Africa—Diamond; S. Afr. Min. Eng. Journ., 1927, 38, Pt. 2, 155–7, 181–2, 225–6, 257–8, 281.

of kimberlite* are known to occur, all of which are barren of diamond, but the country occupies a leading position as a producer of detrital stones.

The deposits from which the bulk of the production has been obtained were discovered in 1908 and extend along the sea coast from near Conception Bay to Chameis, a distance of 275 miles, but are not continuous. Similar diamantiferous deposits have also been proved to exist on Possession Island which lies about 2 miles off the coast in Elizabeth Bay.

The diamond occurs in a series of marine sandstones which form several terraces ranging in age from Middle Tertiary to Recent, and in residual deposits mainly derived from them in which the stones occur in greater abundance by reason of concentration.

These eluvial "gravels," which constitute the chief source of the stones produced, are made up chiefly of rounded and faceted grains of milky quartz, white felspar, yellow chalcedony, banded agate, almandine garnet, epidote, haematite and magnetite with fragments of granite and gneiss, and in their uppermost parts always consist of coarse fragments owing to the removal of the finer particles by wind. In some places this wind action has caused a remarkable surface concentration of diamond in pockets in the underlying limestone. The diamond content of the gravel varies considerably from place to place, and the thickness, which is often only a few inches, reaches as much as 30 feet in places.

The principal deposits, all of which were exploited before the war, lie in the vicinity of Lüderitz Bay and stretch southwards from there to the farm Marmora, a distance of some 70 miles. They are confined to certain valleys and depressions lying parallel to the coast, and diamond is not found farther than 15 miles inland.

Fifteen German companies and one South African company were working the deposits before the war, their output being controlled by the German government, all stones having to be marketed according to a fixed quota through an organisation in Berlin known as the Diamant Regie which in turn sold them to an Antwerp syndicate.

After the war most of these German diamond interests were purchased by a syndicate, the Consolidated Diamond Mines of South-West Africa Ltd. (in which the Anglo-American Corporation is largely interested) which is responsible for 80 to 90 per cent. of the annual sales of diamond. Another firm which has worked diamond on a large scale is Namaqua Diamonds Ltd., who absorbed Kolmanskop Diamond Mines Ltd., the South African firm which worked near Lüderitz Bay before the war. There are other smaller producers.

---

* See page 44.

On the whole the gravels are of very low grade, probably less than 0·2 carats per cubic metre on the average, but some very rich patches have been struck, for instance in the Ida Tal near Pomona up to 200 carats per cubic metre was the yield.

On account of its small diamond content, the gravel has to be excavated and treated on a large scale in order to render the operations remunerative. Electrically driven mechanical excavators, mounted on caterpillar trucks and capable of lifting about 5 tons of gravel at a time, raise the gravel and drop it into trucks for conveyance to the treatment plants.

There are two of these plants, situated at Elizabeth Bay and at Kolmanskop, the former having a capacity of 10,000 tons of gravel per 24 hours. Here the gravel passes through a crusher, logwasher, trommels, and tube mills so as to produce two graded products of 2 to 5·5 mm. and 1·25 to 2 mm. size respectively. Sea water is used for washing and the fines are pumped out to sea.

The graded products are concentrated by means of Schiechel jigs which are of the circular air-plunger type; the concentrates from these are again jigged and magnetically concentrated, the final product being hand picked. The Kolmanskop plant employs dry screening. Grease tables are not employed in these plants as the stones are not amenable to this treatment.

Some indication of the scale upon which operations are conducted may be gathered from the fact that in 1929 Consolidated Diamond Mines removed more than 7 million loads of gravel and recovered 537,141 carats of diamond, an average of 7·5 carats per 100 loads (of 1,600 lb.).

The stones obtained are, on the average, small but of excellent quality and remarkable brilliance, even when uncut. The average size of stones produced in recent years has varied between 5 and 7·5 to the carat.

Owing to the depressed condition of the diamond market the Kolmanskop plant was closed in April, 1930, and the Elizabeth Bay plant ceased working in April, 1931. Namaqua Diamonds Ltd. also ceased operations early in 1931.

The discovery of the rich diamond deposits in Namaqualand just to the south of the Orange River referred to on p. 51, led to very active prospecting on the north bank of the river. In view of the condition of the diamond market and in continuation of its policy with regard to limitation of output in the Union, the Government in 1927 closed to prospecting all surveyed farms along the Orange River and all unsurveyed Government ground up to a distance of two miles from the river. The whole of the Kaokoveld also was afterwards closed to prospecting and pegging for diamonds.

Late in 1928 an intensive campaign of prospecting carried out by Consolidated Diamond Mines on their concessions near the mouth of the river was rewarded by the discovery of diamond-bearing terraces similar to those found in Namaqualand.* The stones themselves are also similar, being of large size and good quality. So far the largest stone found weighed 246 carats and the average weight is about 1½ carats.

These new finds are likely to prove of considerable importance when the diamond market recovers, but owing to the depression which has existed since their discovery they have not yet been worked to any extent. Prospecting operations have been continued, however, in the area north of the Orange river and around Bogenfels, with results which are said to have been very encouraging.

Prior to the discovery of these new deposits, the largest stones were found in the vicinity of Pomona, and there was said to be a gradual decrease in size of stones both northwards and southwards from this centre, and also from the sea inland. The stones show signs of attrition.

The question of the origin of these important diamond deposits is one which has exercised the minds of many workers in this field, and it cannot be said to have been solved. Kaiser considered that the stones came from the interior and were subsequently included in an extensive sandstone sheet, from which they were carried into many later alluvial deposits mainly by Eocene rivers† ; Wagner believed, however, that the parent rock lies submerged off the coast, and argued that the size of stones points to this source being situated close to the Pomona district.‡

Both these authorities were unaware of the existence of the newly discovered, and much richer, deposits both north and south of the mouth of the Orange river. It now appears that the size of stones diminishes as the distance from the mouth of the river increases. The present evidence, therefore, is strongly in favour of the theory that the stones originated in inland deposits from which they were carried by the equivalent of the Orange river in former geological ages, to the sea, to be subsequently reconcentrated by ocean currents, and cast up on beaches near the river mouth.§ A similar view was expressed by Krause in 1910.||

The production of diamond in South-West Africa reached its highest peak in the year before the war when more than 1½ million carats were produced, but this output was exceptional as the

* S. Afr. Min. Eng. Journ., 1929, 40, Pt. 1, 429.
† Die Diamantenwüste Südwest-Afrikas, by E. Kaiser, 2 vols.; Berlin, 1926.
‡ P. A. Wagner, *op. cit.*, p. 98.
§ Diamond-bearing alluvial gravels of the Union of South Africa, by A. F. Williams; Third (Triennial) Empire Mining and Metallurgical Congress, S. Africa, 1930, Pt. 3, No. 2, p. 63.
|| Notes on the German South-West African diamonds, by C. Krause; Trans. Geol. Soc. S. Afr., 1910, 13, 64.

previous level had been less than 1 million carats. Since the war the peak was reached in 1927 when nearly ¾ million carats were obtained. Under the system of controlled output (explained on pp. 24-26, the Consolidated Co.'s quota is 25 per cent. by value.

Other gemstones.—Before the war, *beryl, tourmaline, topaz,* and *rose quartz* of gem quality were exported to Germany but none was produced after the war until 1927 when 7·7 tons of rose quartz and 34 kilograms of beryl were produced and exported.

*Beryl** occurs in the pegmatites of Tonkerhoek (Donkerhoek); in pegmatites at Klein Spitzkopje near Rössing on the Otavi railway east of Swakopmund; and also between Aiais and Gaibes on the Fish river. The beryls of Klein Spitzkopje are especially interesting as they occur in handsome varieties of aquamarine, heliodor (golden beryl) and the unusual "aquamarine-chrysolite", a yellowish-green variety of beryl found mainly in Siberia and Brazil. The heliodor has been found to contain small amounts of uranium oxide and is distinctly radioactive.

The pegmatite veins traverse a dark-coloured biotite-schist, and are extremely variable both in composition and texture, the constituents being quartz, felspar, beryl, tourmaline, biotite and muscovite, with pyrites, wolframite and possibly corundum. Fibrous gypsum and halite fill cracks in the superficial portions of the rock. Some of the quartz is rose coloured. The tourmaline and beryl are both most irregularly distributed through the pegmatite. The former occurs as lustrous black prismatic crystals of triangular cross-section, mostly about an inch long, but sometimes as much as 18 inches long and 9 inches thick. The aquamarine and heliodor are often of excellent quality and when cut produce gems of strikingly handsome appearance.

Gem tourmaline occurs with the beryl in pegmatite at Klein Spitzkopje. It is stated to range in colour from blue through bluish green, pistachio-green and green, to pale yellowish green, with pink varieties occasionally, and to be of good quality and large size.†

Wagner reports the occurrence near Walvis Bay of a remarkable composite garnetiferous cordierite-sillimanite-biotite-gneiss which has disintegrated at the surface into an eluvial gravel containing fine pieces of *cordierite.* He states that many of these are flawless and when cut might yield "water-sapphires" of fine quality.

Lazulite is stated to occur in the Etemba district. It is cut into ornaments and trinkets at Idar in Germany.

---

* Ein neues Beryll (Aquamarin) - Vorkommen in Deutsch - Südwestafrika, by E. Kaiser; Centralblatt f. Min. etc., 1912, p. 385. On some mineral occurrences in the Namib Desert, by P. A. Wagner; Trans. Geol. Soc. S. Afr., 1921, 24, 86–93.

† S. Afr. Journ. Industries, 1921, 4, 868.

South-West Africa Territory.—Diamond production and sales.

Year.	Production.		Sales.		
	Thousands of carats.	Stones per carat.	Thousands of carats.	Value (£1,000).	Value per carat (shillings).
1927 ...	724	5·9	577	1,621	56·15
1928 ...	503	6·3	564	1,390	49·25
1929 ...	597	5·8	533	1,618	60·69
1930 ...	415	5·8	214	640	59·83
1931 ...	72	4·8	103	300	58·18
1932 ...	18	0·9	44	211	95·30

South-West Africa Territory.—Exports of Diamond (Domestic Produce).

Year.	Quantity (carats).	Value (£).
1928	503,143	1,215,820
1929	597,059	1,563,805
1930	414,947	1,184,217
1931	71,532	226,720
1932	17,946	85,440

In 1928, 3·75 tons of *rose quartz* and 48·7 kilos of *tourmaline* were produced and exported. In 1929, 33·2 kilos of *tourmaline* were produced and exported. In 1930, 11·6 kilos of *tourmaline* and 30 kilos of *topaz* were produced, while 6·7 kilos of *heliotrope* and 1·6 kilos of *chrysoprase* were produced and exported, and 10·6 kilos of *tourmaline* were exported.

Tanganyika Territory.*

Diamond.—Although diamond claims had been pegged as long ago as 1910, it was not generally known that a diamond field existed in the district to the south of Lake Victoria until a syndicate known as Tanganyika Diamonds Ltd. examined and commenced washing the ground in 1925.

The deposits lie in granite country, and their nature was in considerable doubt until Wagner made a petrological examination of material in which diamond had been found and pronounced it to be altered kimberlite of the basaltic type.†

The original discovery was at Mabuki some 36 miles south-east of Mwanza, where the diamond deposit consists of a concentration of

* Annual Reports, Mines Department. Shinyanga diamond fields, by E. O. Teale; Geol. Survey Dept., Tanganyika Terr. Short Paper No. 9. The kimberlite and associated occurrences of the Iramba Plateau, by E. O. Teale; Geol. Surv. Dept., Tanganyika Terr., Short Paper No. 10.

† Note on Kimberlite from Tanganyika Territory, by P. A. Wagner; S. Afr. Journ. Science, 1926, 23, 204.

diamantiferous gravel on a kimberlite pipe. Prospecting revealed that the stones were of good average quality and the yield was about 25 carats per 100 loads.

These indications were so important that the Anglo-American Corporation negotiated an option, making an agreement to prove and develop the mine for 18 months from the beginning of 1926, to defray costs and to surrender to the owners half the stones obtained. But the Corporation decided to allow their option to lapse after June, 1927, as the recovery of diamond from 1,999,119 loads washed had been only 17,168 carats (i.e., 8·62 carats per 100 loads), and the property reverted to the owners, who are now operating it.

During 1928, 22,157 stones were obtained from the Mabuki mine, the average weight being just over one carat. During 1929 the output was 30,739 stones, averaging ¾ carat and this was the peak production. It seems, however, that the kimberlite below the gravel has not proved to be payable, and the gravels within the mine area which have yielded a total of about 100,000 carats have already been practically exhausted.

Further prospecting has disclosed several fissures and fissure enlargements containing diamantiferous kimberlite in the Shinyanga district some 60 miles further south, which are at present being actively investigated. About 20 occurrences of kimberlite in all have been found in the Mabuki and Shinyanga districts, some of which have been proved to contain diamond, but up to the present the output has been obtained almost entirely from superficial deposits in the vicinity of the pipes and not from the pipes themselves.

It is of interest to note that these deposits in Tanganyika are the most northerly outcrops of kimberlite so far discovered in the African continent. All the finds are within easy reach of the new railway line from Tabora to Mwanza. Up to the present the stones have been obtained chiefly from detrital deposits in the neighbourhood of a kimberlite occurrence known as the Sultan mine about two miles south of Shinyanga on the west side of Kizumbi Hill. They are on the whole larger than those from Mabuki, averaging 3 carats in weight, with many exceeding 5 carats, and are stated to be of excellent quality, but have an uncommon cushion-shaped mode of growth.

The shallow surface gravels on Claim 3383 to the north of the kimberlite (lower down the valley) yielded 2,700 carats of diamond prior to 1930. In that year, however, the underlying grey grit, which had previously been thought to be decomposed granite bedrock, was also found to be diamantiferous and yielded 1,248 carats from 4,000 loads washed. A diamantiferous terrace deposit has also been found in the Mhumbu valley between Shinyanga and Seke stations.

Kimberlite from the Sultan mine yielded 90·37 carats from 1,008 loads washed, but it has not yet been shown to be economically workable. The adjoining Kizumbi pipe has also yielded diamond.

On account of the rush to peg claims in this area, regulations had to be introduced by the government to control prospectors' activities.

In addition to the discoveries around Mabuki and Shinyanga, later investigations have led to the finding of eleven kimberlite occurrences on the Iramba Plateau over a distance of some 70 miles. Some are of unusual size but their potential economic value has not so far been ascertained.

The question of the origin of the detrital diamond deposits in Tanganyika is one which cannot be said to have been settled. In view of their occurrence above or near to kimberlite necks it was naturally believed at first that they were eluvial deposits derived from the underlying kimberlites, but closer examination, chiefly by Du Toit and Harger, has thrown much doubt upon this supposition and it is now believed that the deposits may be the relics of the fillings of valleys and depressions of an earlier drainage system which bore little relationship to that now in existence. The diamond may in this case have come from other sources than the kimberlites around which it now occurs.

The largest stone so far produced in Tanganyika weighed 92·5 carats, and the most valuable was one of 37·75 carats produced in 1930 valued at £1,698 15s. In 1930 the average weight of stones produced was 0·75 carats.

The Tanganyika Government takes no share of stones produced in the country, but levies a tax of 10 per cent. on the value of stones exported.

Other gemstones.—Almandine-pyrope is found in hornblende-gneiss and detritus near Namaputa in the Lindi Province and was exported to Germany before the war for gem purposes, principally for decorating ecclesiastical ornaments for the Russian market. The stones were cut in Germany and Bohemia and sold as "Fashoda" or "Cape ruby." In 1927, 110 lb. valued at £1,025 was exported to Germany from the Luisenfeld mine, and in 1928, 87 lb. valued at £593, was exported, but the mine then closed down. Small crystals of *pyrope* of good colour are obtained in the Shinyanga district. *Beryl* is reported to occur at the same locality.

Small quantities of *amethyst* are stated to occur in the Pare and Uluguru mountains, and *phenakite* (beryllium silicate) of gem quality has been found in the Kiswiti mountains, east of Mpwapwa.

An occurrence of *moonstone* has recently been reported in the Kondoa-Irangi district.

Tanganyika Territory.—Exports of Diamond (Domestic Produce).

Year.	Quantity (carats).	Value (£).
1928	24,598	152,476
1929	23,290	91,247
1930	13,337	32,962
1931	7,790	9,866
1932	1,391	1,666

Union of South Africa.*

For many years the Union of South Africa has been the world's leading producer of precious stones, its diamond fields being the richest so far discovered. The diamond occurs both as a primary constituent disseminated throughout a curious igneous rock known as kimberlite, and also in detrital deposits.

Primary diamond deposits.—Kimberlite or "blue ground" is a peculiar soft greenish-blue ultrabasic rock, described as a peridotitic tuff or breccia, with a serpentinous groundmass which contains numerous serpentinized pseudomorphs after olivine, together with chrome-garnet, ilmenite, brown mica and a great variety of other minerals. The rock is of somewhat variable character, but practically always contains numerous inclusions of rock derived from the surrounding strata together with xenoliths brought up from below. Towards the surface it becomes weathered and converted by oxidation into a soft, yellowish or reddish, speckled product known as "yellow ground."

Kimberlite occurs principally in funnel-shaped bodies known as "pipes," but also in dykes and sills. These pipes are widespread in South Africa and were probably formed at the close of the Cretaceous period. Scores of them, varying in diameter from 50 feet to over half a mile, have been located from Heidelberg in the Cape Province to Katanga in the Belgian Congo, but in the Union they chiefly occupy an area stretching from Namaqualand and Sutherland to Pretoria with occurrences along the Free State-Basutoland border and in Griqualand East and Gordonia.

It is a characteristic of these vents that they often occur in clusters, but although each cluster may consist of a dozen or more pipes it is uncommon for more than one or two to be sufficiently diamantiferous to be profitably worked; and the majority are quite barren.

Diamond was originally discovered in South Africa in 1867 in alluvial deposits on the banks of the Orange River near Hopetown, but the much richer pipe deposits began to come to light in 1870, discoveries being made on the farm Jagersfontein near Fauresmith in the Orange Free State, and farther north across the Griqualand West border at Dutoitspan, on the farm Bultfontein, and two famous pipes (afterwards known as the Kimberley and De Beers mines) on the farm Vooruitzigt, in what was later known as the Kimberley district. A further discovery

---

*** The diamond fields of Southern Africa, by P. A. Wagner; Johannesburg, 1914. Geology of South Africa, by A. L. Du Toit; Edinburgh, 1926. Present day practice of diamond mining, including recovery, by A. F. Williams and J. Harbottle; Third (Triennial) Empire Min. and Met. Congress, S. Africa, 1930. Diamond-bearing alluvial gravels of the Union of South Africa, by A. F. Williams; *ibid.* The genesis of the diamond, by A. F. Williams; London, 1932, (2 vols., 636 pp.).**

was made about the same time at Koffyfontein in the Orange Free State about half-way between Jagersfontein and Kimberley.

At first these early mines were staked and worked by the claimants in much the same way as the alluvial deposits, but when it was found that the diamond values continued in depth, this method became impossible, the workings were merged into huge pits and the controlling interests fell almost wholly into the hands of one company, the De Beers Consolidated Mines, Ltd., largely owing to the efforts of Cecil Rhodes.

Among later important discoveries in the Kimberley district should be mentioned the Wesselton, St. Augustine's, Taylor's Kopje, Otto's Kopje and Kamfersdam mines; in the Lower Vaal and Harts River district, the Frank Smith mine and the Newlands pipes; in the Koffyfontein district, the Klipfontein and Ebenhaezer mines; in the Boshof district, the New Eland, Roberts Victor and Blaauwbosch mines and in the Kroonstad district, the Voorspoed and Crown or Lace mines.

The production from pipes entered upon a new phase with the discovery in 1902 of the pipes to the north-west of Pretoria in the Transvaal, which ultimately led to the opening of the Premier mine on the farm Elandsfontein No. 85, now the largest diamond mine in the world. The latest discoveries of valuable pipes have been in the Postmasburg district of Cape Province.

Although all the above and many other mines have from time to time been worked, the industry is closely controlled and for some years the majority of them have either been held in reserve or definitely closed, only those pipes which can be most economically worked or which yield especially fine stones being operated.

In recent years the principal mines producing diamond have been the Wesselton, Bultfontein and Dutoitspan in the Kimberley district; the Premier in the Pretoria district; the New Jagersfontein in the Fauresmith district, O.F.S.; the Koffyfontein in the Jacobsdal district, O.F.S.; the Crown, or Lace, in the Kroonstad district, O.F.S.; the West End at Postmasburg in the Hay District, C.P.; and several small intermittent producers such as the Frank Smith-Weltevreden in the Harts River valley, the New Eland in the vicinity of Kroonstad and the Monteleo and the Star in the Theunissen district, O.F.S.

The great bulk of the output is directly under the control of the De Beer's Company.

The method of mining kimberlite from the pipes varies slightly in different mines, but in general the material is removed to as great a depth as is economically and safely possible by opencast methods, after which main shafts are sunk in the country rock sufficiently far from the pipe to ensure safety from subsidence, and from these, main haulage drifts are driven into the pipe at regular vertical intervals. Horizontal working galleries are driven across the pipe at intervals of 40 feet, and at right angles to these run smaller galleries.

The blue ground is removed by a system of caving commencing from the face farthest from the shaft and working back towards it, and when each level has been drawn back a distance from the walls, stoping is commenced at the next lower level so that the work progresses in a series of steps. The blue ground is trammed to the shaft and dumped into bins from which it is hoisted in skips.

The Premier mine,* until it was closed in 1932, was still being worked as an enormous open pit, the blue ground being removed in a series of terraces 50 feet deep; the excavation being done by blasting and drilling, and hand loading methods employed as being the most economical. The pipe is roughly oval, about ½ mile long by ⅓ mile across; development of the 660 foot level commenced in 1931, and it has been stated that it may be possible to continue the open excavations down to about 1,000 feet. In the case of the Wesselton and Bultfontein mines, underground methods had to be commenced after about 250 feet.

The blue ground fresh from the mine is hard and compact, but when exposed to atmospheric influences it soon breaks up. It was formerly therefore the practice at most of the mines to spread it out on the open veldt to a depth of a foot or so, and leave it for several months exposed to the weather, with occasional watering and harrowing to aid disintegration. Diamond is so sparsely distributed that few persons have ever seen it in the blue ground.

In recent years it has become customary to accelerate the process of recovering diamond from the blue ground by dispensing with the long process of weathering and substituting for it an elaborate system of stage crushing, using corrugated rolls so as to avoid breaking the stones. Sometimes a combination of weathering and crushing has been employed.

After this preliminary breaking down, concentration is performed in large, shallow, rotary iron pans, about 14 ft. in diameter, in which a reduction to about one per cent. of the original bulk is effected. The concentrates are then sized and jigged.

The next step in recovering the diamond is due to the ingenuity of F. Kirsten, who in 1897 discovered the remarkable affinity of diamond for grease. The jig concentrates are run over grease-tables, which consist of oscillating inclined sheets of galvanized iron covered with grease, to which the diamond crystals, together with a little ilmenite and pyrites, readily adhere, the useless material passing on. A second treatment ensures a complete recovery. These machines are enclosed with netting to prevent theft, and the stones are later recovered by scraping the tables and

* **Premier Diamond Mine, by Ralph Stokes; Mining Mag., 1912, 7, 366.**

dissolving the grease by treatment with hot alkali and acid solutions. Modified Frue vanners with greased belts have been employed for the same purpose as the grease-tables.

The final concentrate is subjected to magnetic separation, after which the stones are hand-picked and sorted.

In general, mine stones are smaller than those obtained from alluvial deposits, and the product of each mine is sufficiently distinctive for an expert to identify the source from which any particular stone was obtained.

Many of the South African mine stones are yellowish and "off-coloured," especially in the Kimberley district, the proportion of the most highly prized blue-white stones in some of the mines being very small. The Wesselton and Bultfontein mines are exceptions to this. At the Jagersfontein mine where yellow stones are rare, the blue-white stones, which predominate, are very largely cleavage-fragments, and many of the stones are disfigured by black spots. The Koffyfontein group of pipes contains a good proportion of blue-white stones, and so does the New Eland mine. The Premier mine produces, in addition to a greater quantity, a greater variety of stones than any other mine, including much low-grade material and bort. The bulk of the stones from the Kimberley mines are known as "capes" or "silver capes" and are slightly yellow tinted.

As a rule fancy stones are not abundant in South Africa, but the Jagersfontein mine has produced a number of sapphire-blue stones; the Bultfontein, heliotrope stones; the Voorspoed, rose-pink stones; the Wesselton, golden-yellow stones; several mines have yielded green stones, and red ones have also been produced.

The proportion of diamond in the blue-ground varies very considerably in different mines and in different parts, and at different depths in the same mine. Excluding surface enrichment due to weathering, it has been noted that there is in all cases a decreasing yield of diamond as the mining operations descend. The yield is always quoted in carats per hundred loads, a load being 16 cubic feet of blue ground weighing about 1,600 lb.

At present the Bultfontein kimberlite is the richest in diamond content, producing about 31 carats per 100 loads washed, as compared with 23 at the Wesselton, 16 to 18 at the Premier, 16 at the Dutoitspan, 9 at the Koffyfontein and 7 at the West End.*

It was stated in 1929 that during the 25 years of its operations the Premier mine had produced about 5½ tons of diamond from about 100 million tons of total rock excavated, which is about four carats per ton on an average.

* Mining Year Book, by W. E. Skinner; 1932.

As regards the average size of stones produced, according to Langley,* the Jagersfontein mine produces 50 per cent. of stones of 1 carat and over, the De Beers group of mines 40 per cent and the Premier 17 per cent. The De Beers group includes the Wesselton and Bultfontein mines which produce a large proportion of small stones.

Occasionally stones of large size are met with, the Jagersfontein being especially notable in this respect, at least six stones of over 500 carats having been produced there, while the Dutoitspan has produced a number of yellow stones weighing over 200 carats.

The famous *Cullinan* diamond, by far the largest precious diamond ever found, came from the Premier mine in 1905. Uncut, it weighed 3,106 metric carats (over 1⅓ lb.) and was itself probably a cleavage fragment of a larger octahedral stone. It has been cut into 105 brilliants, all of exquisite quality, the two largest of which are a drop weighing 530·2 metric carats, and an oblong brilliant of 317·4 metric carats, both in the British Crown Jewels.

The same mine has also produced stones of 1,640 and 1,195 carats, which consisted mainly of bort and therefore were of small worth, and at least fifteen other stones of over 300 carats each.

Other exceptionally large stones from South African mines include the *Excelsior* weighing 971¾ carats; the *Jubilee*, a flattened octahedron of 640 carats, which was cut into a perfect brilliant of 245 metric carats; four others of about 600, 567, 537 and 507 carats, and fourteen others weighing over 300 carats each, all from the Jagersfontein mine; two octahedral stones of 503 and 428½ carats and nine others weighing over 300 carats each from the De Beers mine; six stones of more than 300 carats each from the Dutoitspan mine, and the famous *Tiffany Yellow*, a magnificent yellow stone cut into a double brilliant with 101 facets, which weighs 128·5 metric carats, from the Kimberley mine.

South African diamond is stated to vary somewhat in hardness in the different pipes and to be on the whole less hard than diamond from elsewhere. The Voorspoed mine was said to produce the hardest stones and the Premier next, while those from Dutoitspan and Jagersfontein were said to be harder than those from the Kimberley, De Beers and Bultfontein mines. Such variations in hardness as exist between different stones are presumably slight, and possibly due to differences in internal structure arising from varying conditions of growth. Slight as they may be, they affect the operation of cutting, since the cutting discs and laps are themselves armed with diamond powder. A detailed account of the varieties of diamond crystals found in the South African mines has been given by Sutton.†

---

* C. E. H. Langley in Ann. Rept. Dept. Mines & Industries, S. Africa, 1924.

† Diamond, a descriptive treatise, by J. R. Sutton; London, 1928.

The probable origin of diamond in the kimberlite is a subject about which there has been much controversy, and to which many authorities have contributed their opinions.

E. J. Dunn and H. C. Carvill Lewis suggested that the diamond originated by the action of molten kimberlite on carbonaceous material derived from the invaded rocks (Karroo shales), but many diamond crystals have been found in kimberlite which has not pierced such rocks.

T. G. Bonney, who proved the existence of diamond in masses of eclogite enclosed by the kimberlite, concluded that kimberlite was not the source of diamond, but that the latter was an original constituent of pre-existing eclogite (a less basic rock). He held that the diamond had been formed, like the garnet and pyroxene of the eclogite, in some deep-seated holocrystalline rock which subsequently suffered explosive disruption, and therefore its presence in kimberlite was purely accidental. This view is supported by the fact that most of the kimberlite pipes are devoid of diamond, and by the occurrence in the diamantiferous pipes of large amounts of broken crystals and cleavage fragments, but is difficult to reconcile with the rarity of eclogite xenoliths in some of the most productive diamond mines.

According to F. W. Voit, G. S. Corstorphine, A. F. Williams and several others, the diamond has crystallized entirely from kimberlite magma; while according to P. A. Wagner and A. L. Du Toit, the bulk of the diamond crystallized from kimberlite magma, although some may have been brought up from below as the result of the breaking up of pre-existing diamantiferous eclogite. The last seems to be the view most generally accepted at present, but there is much difference of opinion as to whether the diamond crystallized out of the kimberlite magma before or subsequent to intrusion, or at both stages.

Those desirous of pursuing the study of this subject in greater detail will find many references in the bibliographies compiled by A. A. Julien* and P. A. Wagner,† as well as a discussion of the problem in the recently published book by A. F. Williams.‡

Alluvial diamond deposits.—Small greenish diamond crystals are recovered from time to time by gold mining companies working on the Rand banket, which are doubtless of detrital origin, derived presumably from pre-Witwatersrand formations farther to the north;§ but the great bulk of the alluvial stones obtained in the

---

* A bibliography of the diamond fields of South Africa, by A. A. Julien; Econ Geol., 1909, 4, 453–469.

† *Op. cit.*

‡ *Op. cit.*

§ R. B. Young; Trans. Geol. Soc. S. Afr., 1913, 16, 39. E. T. Mellor; Journ. Chem. Met. Min. Soc. S. Afr., 1916, 16, 193. J. G. Lawn, Presidential Address for 1924; Proc. Geol. Soc. S. Afr., 1925, 27, xix.

Union and South-West Africa comes from marine and river gravels of various ages from Eocene to Recent.

The principal deposits lie in the valley of the Vaal river from Standerton to its junction with the Orange river; in the upper part of the valley of the Harts river; in the Lichtenburg-Ventersdorp district; and on the Namaqualand coast around Port Nolloth and the mouth of the Orange river. Numerous scattered occurrences in the Orange river valley; on the Kaap plateau; in the Pretoria district; and in the Limpopo valley near Messina, are of lesser importance.

The workings in the upper part of the Vaal river lie partly in the Transvaal and partly in the Orange Free State and include the deposits near Vereeniging, Parys and Potchefstroom; the diggings in the Schoon Spruit valley and at its junction with the Vaal around Klerksdorp and Eastleigh; the Wolmaranstad diggings; the Bloemhof district fields which include the famous farms London and Mooifontein and extend almost to the Harts valley; and the Christiana diggings.

Below these the Vaal river enters the Cape Province and here the gravels which are known as the Griqualand West deposits were, until the development of the very rich Lichtenburg fields in 1926, the chief source of supply of alluvial stones in South Africa. This area embraces the famous deposits around Barkly West, the centre of all alluvial activities for many years, and includes the Delports' Hope, Longlands, Gong Gong, Good Hope, Bad Hope, Holsdam, Hebron, Klipdam, Slypklip, Windsorton and other famous diggings which have produced many of the finest stones found in South Africa. As recently as 1928, a stone was obtained on the Elandsdrift Estate, in this district, which weighed 412 carats and was said to be the largest alluvial stone yet found. A rough stone of 296 metric carats found at Waldeck's Plant in 1872 became the famous *Stewart* diamond, a slightly yellowish brilliant of 123 metric carats.

In the upper Harts valley the principal deposits are situated around Schweizer Reneke; they are almost continuous with the diggings to the north of Bloemhof.

The development of the very extensive diamond fields which occupy an area of some 1,500 square miles in the Lichtenburg-Ventersdorp district of the Western Transvaal was commenced in the summer of 1926 and the area rapidly assumed the premier position as a source of alluvial diamond. The most important centres of production are the farms Uitgevonden, Grasfontein, Ruigtelaagte, Klipkuil, Welverdiend and Manana, and in 1927 this field provided over 80 per cent. of the Union's alluvial production. Here the diamond-bearing gravel is intimately associated with a cherty conglomerate in a dolomitic limestone, upon the eroded surface of which it was deposited, and is thus quite a different type of occurrence from that in the Vaal and other river valleys.* These fields contain a large number of small stones and a high percentage of broken stones and " rubbish ".

The most recently discovered alluvial field is that stretching along the sandy coast of Namaqualand, Cape Province†. Occasional stones had been found here before the war, but the district did not receive great attention from prospectors until 1925, when finds were made south of Port Nolloth, at The Cliffs just north of the same town, at Buchuberg 40 miles further north, and at the mouth of Buffels river, 32 miles to the south. In the following year a systematic search led by Merensky brought to light the existence of a diamond field stretching along the coast from the mouth of the Orange river down to the Groen river. For the most part the deposits are deeply buried by sand, surface limestone and barren gravels; they are very patchy and situated in a country almost barren of water. The diamond chiefly occurs in raised marine shingle beaches ranging in age probably from Pliocene to Recent, deposited at different levels as the sea receded from the land. Fossils provide evidence for correlating the horizons. The richest area at present known is that to the north-east of Alexander Bay, where the stones occur most abundantly in a shingle bed associated with a profusion of fossil oyster shells (*Ostrea prismatica*), known as the Oyster Line, which has been traced a distance of ¾ mile. During the prospecting operations in this district a parcel of stones was produced which weighed 12,240 carats and was valued at £154,000; over £12 per carat. It was perhaps the finest assemblage of uncut stones ever brought together, and contained a stone of 71·5 carats sold for £8,000, said to be the most valuable detrital diamond found in South Africa. Among the stones were some which closely resembled Dutoitspan mine stones and others like those from the Wesselton, Koffyfontein and Kimberley mines, some of the blue-whites being indistinguishable from Hopetown alluvial stones, but there were many which could not be matched elsewhere. Other finds were made near the mouths of the Kamma, Buffels and Groen rivers. The source of the gems is obscure; they may have been brought down in whole or in part from inland sources, known or unknown, by rivers, or they may have been wholly or partially derived from sources now under the sea.

* On the occurrence of diamonds associated with the chert beds of the dolomite series in the districts of Ventersdorp and Lichtenburg, by David Draper; Trans. Geol. Soc. S. Afr., 1927, 30, 57. The genesis of the diamond, by A. F. Williams, pp. 567–592.

† The diamond deposits on the coast of Little Namaqualand, by P. A. Wagner and H. Merensky; Trans. Geol. Soc. S. Afr., 1928, 31, 1–41. The discovery of the Namaqualand diamonds, by E. Reuning; Min. Indust. Mag. S. Afr., 1928, 7, 51, 87, 177, 219.

The provisions of the Precious Stones Control Act, referred to in some detail on p. 54, enabled the State authorities to prohibit further prospecting, and except for an area of 100 claims near Alexander Bay allocated to the Merensky Syndicate, which did most of the pioneer work in this field, and the farm Kleinzee at the Buffels river mouth, the government prohibited the working by individuals of the rest of the deposits.

The control of the bulk of the potential diamantiferous deposits along the coast south of Port Nolloth has been obtained by the Cape Coast Exploration Co., (itself controlled by the Anglo-American Corporation). This company is at present able only to operate on Kleinzee, where the production and sales are limited by the Government to £6,000 per month; but to the end of June 1929 the production has been 61,000 carats valued at £338,600.

An area of some twenty square miles near Alexander Bay was fenced in, patrolled by police and exploited by the State, the stones being transported by aeroplane to Cape Town. Up to the end of March 1929 the production from the State diggings was about 600,000 carats valued at about £6½ millions, but no separate record of production appears to have been made for these diggings since then. In 1931 the washing and screening plant was electrically driven. The Merensky Syndicate is stated to have worked out its claims, but no details of its production appear to have been published. The production of alluvial diamond in Namaqualand in 1931 amounted to 137,895 carats.

It may be of interest to record that X-rays have been employed in the detection of theft of diamond from the Namaqualand deposits.

The working of alluvial diamond properties in South Africa, unlike the pipes, has always been in the hands of innumerable individuals operating their own small properties. The distribution of diamond in the gravels is very irregular so that diamond digging is a very uncertain form of occupation, and while in many instances substantial fortunes have been made by lucky diggers in an incredibly short space of time, the great majority have generally been able only to make a very modest income out of their diggings and great numbers are little, if any, better off than the natives working for the big syndicates operating mines.

The usual method of working diamantiferous gravel is to excavate by pick and shovel down to bed-rock, screening the loosened gravel through coarse screens, rejecting the coarse material and then sieving the finer material in a rocking machine known as a "baby" (after M. Bébé its inventor) which eliminates the fine sand.* The resulting material known as "wash" accumulates until there is sufficient to treat in the next machine which

---

* The alluvial diamondiferous deposits of South and South-West Africa, by F. C. Cornell; Journ. Roy. Soc. Arts, 1921, 69, 136.

is an iron pan 4 to 6 feet in diameter and one foot deep, set in a heavy wooden frame, in which a series of arms set with knives are rotated by a crank operated by hand by native labourers. The wash is mixed with sand or loam and water and fed into the pan in a muddy consistency, where the constant rotation of the arms causes the heavier minerals including the diamond to find their way to the bottom of the pan whence they are removed from time to time by means of a trap. Operated under the direction of an experienced digger these rotary machines are very efficient, but skill and care must be exercised, especially in keeping the " puddle " at the correct consistency, or many flat cleavage flakes and " macles " may be lost. The final concentration is done by skilful manipulation of a " gravitating sieve " held under water, followed by hand picking on a sorting table usually performed by the digger himself.

Occasionally the diggings have been carried right into the bed of the Vaal river by means of breakwaters and dams and very rich pot-holes have been discovered in this way, but the work is hazardous. Schemes have from time to time been devised for diverting the river itself at certain points from its normal course in order to recover the gems from the drained bed. Deep gravels have sometimes been opened up by means of shafts and drives.

Various theories have been evolved to account for the origin of these alluvial fields; it seems probable that the diamond has been brought down by the former equivalents of the Vaal and other rivers which are assumed to have flowed over the pipes, which are regarded as the primary source*; another view is that diamond was removed from the pipes and distributed by glacial action; again it has been suggested that the diamond came originally not from kimberlite pipes but from a peculiar amygdaloidal andesite which crops out in the river bank in many places.† While the origin of the diamond remains obscure it is likely that, in many instances, many of the stones have been derived from nearby pipes, although they are always accompanied by stones of unknown origin. The South-West Africa and Namaqualand coast deposits have been in part at least derived from marine sediments, but there is diversity of opinion as to whence the diamond originally came.

The high average size and quality of alluvial stones from the older diggings has always been a noticeable feature. Indeed, for several years up to 1925 the value per carat of alluvial stones was nearly three times that of the mine stones. But after 1925 a great change came over the whole diamond industry of South Africa. It was largely due to the finding and rapid development

---

*** A. F. Williams, *op. cit.*, discusses the problem in great detail.**

† The occurrence of diamonds in Dwyka conglomerate and amygdaloidal lavas; and the origin of the Vaal river diamonds, by H. S. Harger; Trans. Geol. Soc. S. Afr., 1909, 12, 139–158.

of the large diamond fields around Lichtenburg which have been previously referred to. The effect of this is illustrated by the statistical table on p. 57.

It will be seen that whereas the alluvial production in 1925 was normal at about 240,000 carats with an average value of nearly £8 per carat, in 1926 the quantity more than trebled to about 800,000 carats, worth less than £5 per carat, and in 1927 there was a further enormous increase in quantity to more than 2,300,000 carats, while the value fell away to 53s. 6d. per carat. During the same period the mines production remained roughly constant at about 2¼ million carats valued at about 55s. per carat. Thus for the first time the production and value of mine stones and of alluvial stones were approximately the same.

But the alluvial fields of the Union were largely uncontrolled and were flooding the market with stones to the detriment of prices, so that a serious situation had thus suddenly arisen, and steps had to be taken both by the large diamond producers and the Union Government to ensure that the value of the diamond, which was already tottering, should not suffer a severe slump.

As the low-grade alluvial output from Lichtenburg came largely into competition with the output of the Premier mine, an arrangement was made whereby the Premier did not contribute its quota to the syndicate during the latter half of 1927. The big diamond-mining companies in addition bought in large quantities of alluvial stones.

In November, 1927, the amended Precious Stones Control Bill was passed through a joint sitting of both Houses of Parliament. Action by the Government had become more pressing in view of the discovery of the rich Namaqualand field, the production from which it was felt might, if allowed to proceed unchecked after the manner of the Lichtenburg field, result in a great deflation of prices and probable panic in the diamond market.

The bill enacts that the right of mining for and disposing of precious stones is vested in the Crown, and amongst other things it provides that the Governor-General may determine the maximum quantity in value of precious stones recovered from alluvial workings or disposed of after being so recovered. Its provisions are, in fact, aimed not only at securing general control of the industry and uniform procedure in all the Union's provinces, but especially at the control of alluvial production. To provide a respite, the first action taken was the prohibition of all prospecting for diamond for one year from 16th December, 1927. With slight modification, this restriction still remains in force, and it undoubtedly had much to do with the re-establishment of the industry on a sound footing.

The effect of these actions was that the alluvial production fell by nearly one million carats in two years and the quality of the stones sold improved. The high value of alluvial stones in 1928 was due in part to the fact that in that year nearly one million carats of high-grade stones from the State workings in Namaqualand were included.

The buying-in of large quantities of alluvial stones by the mining companies necessitated some curtailment of work in the mines, but in order to avoid extensive unemployment among mine workers, a considerable output was maintained, and this has led to an accumulation of unsold stones in the hands of the producers. Recently a new company (the Diamond Corporation) has been formed to take over and hold this surplus until such time as it can be marketed without fear of causing a depreciation in diamond values.

The world-wide depression in trade which became evident in 1930 and acute in 1931, and the consequent lull in the demand for diamonds, especially in the United States, which is the principal market for these luxuries, had a very severe effect upon the diamond industry of South Africa. All the smaller mines closed down in 1930 and the larger producers greatly curtailed output in 1931. Ultimately in March, 1932, all the diamond mines of the Union and of South-West Africa were closed in view of the enormous stocks of rough stones on hand and so as to minimise the risk of a slump in diamond prices.

The question of establishing a diamond-cutting industry on a much larger scale than hitherto in the Union has for a long time been the subject of discussions. As the result of popular agitation, a large cutting plant was established at Kimberley in 1928 by the aid of a State subsidy, the big producing companies erected another at the same place, and several smaller concerns augmented the number which previously existed. Expert cutters were brought from Holland and Belgium to initiate the industry and train local labour. These efforts have not yet met with unqualified success.

Other gemstones.—Besides diamond, several other gemstones occur in the Union of South Africa, but not in sufficient quantity to give rise to any important industry. *Emerald* was discovered in 1927 in the Leydsdorp district, Transvaal. The claims are situated 12 miles E.N.E. of Gravelotte Station on the Zoekmakaar-Komatipoort branch line, where a shaft known as the " Somerset Mine " has been sunk into the deposits by the Beryl Mining Company.* The emerald, together with much beryl of more common character, occurs in mica-schist of the Swaziland System where the latter has been intruded by veins of pegmatite. The beryl and emerald are accompanied by tourmaline, quartz, apatite, felspar and molybdenite, the emerald being commonly enclosed in a sheath of biotite flakes.† The emerald crystals take the

*** Report on Somerset emerald mine, by P. Kovaloff; S. Afr. Min. Eng. Journ., 1928, 39, Pt. 1, 101.**

† The Barbara beryls, by J. M. le Grange: Trans. Geol. Soc. S. Afr., 1929, 32, 1–25.

usual prismatic form, ranging to 2 inches in length, and while most of them are (as is usually the case) cracked and flawed, cloudy and of variable colour, many yield pieces of true transparent emerald sufficient to cut stones of from ½ to 5 carats. Gems that have fetched £100 per carat have been produced. In 1930, about 12 lb. of emerald crystals were being sent to London cutters each week.

At the end of 1929 the area of the opencast working was about 40,000 square feet and the greatest depth 40 feet. Machinery has been installed capable of producing 200 tons of emerald-bearing schist per day, the emerald content of which is about 1¼ lb. per ton. Only a small proportion of this, however, is suitable for cutting into faceted gems, much of the rest being cut *en cabochon* and in other round or oval forms at Idar (Germany), Paris, Geneva, and in China and India. At first sorting was done by hand, but owing to labour difficulties a mechanical treatment plant has been installed. A number of other firms have taken up holdings in the district, but only the Beryl Mining Co. and Cobra Emeralds, Ltd., appear to have been producers. Sales and shipments in 1929, 1930, 1931 and 1932 have been 49,887, 36,431, 46,178 and 8,085 carats respectively.

Emerald has frequently been reported to occur in the Kalahari desert, but no details appear to be known as to the localities.

A vein of *amethyst*, accompanied by *rose quartz* and *cairngorm*, has been opened up in granite near the Yokeskei river bridge on the Pretoria road just north of Johannesburg. Amethyst has been exported in 500 lb. lots to Europe, America and the Far East at prices ranging from 2s. 6d. to 8s. 6d. per lb.

Garnet occurs in the river diggings associated with diamond. The deep blood-red chromiferous *pyrope* was at one time in some demand as a gem, and was marketed under the name of "Cape ruby." The best gems came from the De Beers and Kimberley mines, but garnet is no longer fashionable and the demand has practically ceased. A massive deposit of the lime-garnet *grossular*, of a light green colour, occurs on the farms Buffelsfontein No. 205 and Turffontein No. 356, about 40 miles west of Pretoria, in the norite margin of the Bushveld Complex.* The material somewhat resembles jadeite, and has been worked by South African Jades, Ltd., and sold as a substitute for this stone. In 1925 "jade" to the value of £323 was produced and a further £38 worth in 1929.

Among other stones which are more ornamental than precious may be mentioned the "hawk's-eye" and "tiger's-eye," sometimes known as "crocidolite gems," which are the result of

* On "jade" (massive garnet) from the Bushveld in the Western Transvaal, by A. L. Hall; Trans. Geol. Soc. S. Afr., 1924, 27, 39.

secondary silicification of blue asbestos fibres, and occur chiefly on the farms Naauwpoort and Leelykstaat in the Hay district of Cape Province; and "verdite," a beautiful green serpentinous rock from the Barberton district, Transvaal.

Union of South Africa—Diamond production.

Year.	Mine Production. (including debris washers).			Alluvial Production.		
	Quantity (Thousands of carats).	Value (£1,000).	Value per carat.	Quantity (Thousands of carats).	Value (£1,000).	Value per carat.
			s. d.			s. d.
1913 ...	5,089	10,270	40 4	212	1,120	105 11
1914 ...	2,728	4,910	36 0	148	577	78 1
1915 ...	6	8	26 0	100	392	78 3
1916 ...	2,236	4,780	42 9	172	949	110 3
1917 ...	2,792	6,672	47 10	188	1,042	110 11
1918 ...	2,457	6,150	50 1	147	965	131 0
1919 ...	2,442	8,994	73 8	215	2,741	254 9
1920 ...	2,385	12,321	103 4	227	2,441	214 9
1921 ...	676	2,209	65 4	152	895	118 1
1922 ...	466	907	39 0	204	1,360	133 4
1923 ...	1,809	4,380	48 5	244	1,658	135 8
1924 ...	2,153	5,883	54 8	288	2,150	149 7
1925 ...	2,191	6,292	57 5	239	1,907	159 5
1926 ...	2,410	6,700	55 7	808	3,984	98 7
1927 ...	2,390	6,194	51 10	2,318	6,199	53 6
1928 ...	2,258	5,616	49 9	2,115	11,062	104 7
1929 ...	2,294	5,767	50 3	1,368	4,823	70 6
1930 ...	2,245	5,275	47 0	919	3,065	66 9
1931 ...	1,472	2,245	30 6	647	1,937	59 11
1932 ...	310	377	24 4	488	1,302	53 4

Union of South Africa.—Comparison of Diamond production and sales in recent years.

Year.	Total Production.			Total Sales.		
	Quantity (Thousands of carats).	Value (£1,000).	Value per carat.	Quantity (Thousands of carats).	Value (£1,000).	Value per carat.
			s. d.			s. d.
1927 ...	4,708	12,392	52 8	4,256	11,819	55 7
1928 ...	4,373	16,678	76 3	3,693	11,105	60 2
1929 ...	3,661	10,590	57 10	3,082	12,426	80 8
1930 ...	3,164	8,341	52 9	1,893	5,980	63 2
1931 ...	2,119	4,183	39 6	1,524	3,292	43 2
1932 ...	798	1,680	42 1	868	1,523	35 1

Union of South Africa—Exports of Precious Stones (Domestic Produce).

Variety.	1928.	1929.	1930.	1931.	1932.
Diamond—					
Rough					
Quantity (carats).	3,541,289	2,776,699	1,526,398	1,725,185	773,965
Value ... (£)	*8,888,416*	*10,751,126*	*4,057,638*	*2,744,150*	*1,176,204*
Cut					
Quantity (carats).	(*a*)	35,387	49,764	43,553	*45,899*
Value ... (£)	(*a*)	*1,322,612*	*1,423,574*	*829,350*	*779,319*
Crocidolite Gems—					
Quantity (lb.) ...	—	4,080	2,565	3,580	*120*
Value ... (£)	—	*100*	*122*	*142*	*3*
Other Precious Stones—					
Value ... (£)	*596*	*103*	*763*	*258*	—

(*a*) Information not available.

Canada.

The occurrence of *diamond* in Canada has not yet been proved. It was formerly thought that some crystals obtained during the chemical examination of several Canadian chromite samples consisted of diamond, but these are now believed to have been periclase produced during the fusion for chemical analysis, and other alleged finds in British Columbia have proved to be garnet.*

On account of the fact that diamond has been found occasionally in glacial deposits in the United States, part of which may have originated in Canada, a good deal of prospecting has been done in similar deposits in Canada, especially in the vicinity of the mouth of Bell river on Matagami lake, Quebec, but without result.

There are numerous occurrences of semi-precious stones in Canada, but none is of special importance. *Olivine* of gem quality is found near the molybdenite claims on Timothy mountain in the Clinton district, British Columbia, where it occurs as crystalline masses scattered through basalt. It does not appear to have been used in jewellery. *Tourmaline* of gem quality is stated to occur in the Leduc mine, Wakefield county, Quebec, and fine crystals of *apatite* are found in the Bancroft area. *Turquoise* of gem quality has been found in the Central district of British Columbia at a locality which is very difficult of access.

Amethyst and *agate* occur together along the north shore of Lake Superior and on the adjacent islands, and some good pieces of amethyst have come from the mouth of Mackenzie river. Some fine amethyst has been obtained from the trap rocks along the

* Communication received from Dept. Mines, Canada.

Nova Scotian shore of the Bay of Fundy, where it is accompanied by other varieties of quartz, and some handsome specimens of agate, carnelian, etc. have been found in the same locality. The melaphyres of the Hudson Bay coast yield a variety of forms of chalcedony.

Labradorite felspar is found in north-eastern Quebec, especially along the Romaine river above the Burnt lakes.

Although no *beryl* of gem quality has been found in Canada, several occurrences of this mineral in pegmatites are known, some of which may prove to be of value as sources of supply of beryllium ore. Among these may be mentioned deposits near Quadville, Renfrew County, Ontario; those associated with the molybdenite deposits south-west of Amos, in the Abitibi district, Quebec; and more recently discovered pegmatites in the Lac du Bonnet area, Manitoba.

Canada.—Imports of Diamond.

Year.	Industrial Stones Value (£).	Gems (unset). Value (£).
1928	468,237	698,480
1929	557,385	742,659
1930	295,806	413,614
1931	93,581	178,399
1932	32,499	106,891

Newfoundland.

Most of the *labradorite* used for ornamental purposes comes from the anorthosite rocks which compose the coast and islands in the vicinity of Nairn, Labrador.

The best material is said to be obtained from a quarry on Napoktulagatsuk island, between Paul island and the mainland, where the anorthosite is cut by dykes of aplite and pegmatite.

British Guiana.*

Diamond was discovered in the Puruni district of British Guiana in 1887 while washing stream gravels for gold, and three years later stones were obtained from the Putareng creek of the Mazaruni river, these finds being closely followed by others in the same area.

* Rept. Lands and Mines Dept., Brit. Guiana (Annual). Rept. of the preliminary survey of the Mazaruni and Puruni diamond fields, by H. J. C. Conolly; 1925. The alluvial diamonds of British Guiana, by J. H. Mitchiner; Mining Mag., 1927, 36, 73–83. Rept. on the preliminary geological survey of the Potaro-Ireng district, by Smith Bracewell; Brit. Guiana Combined Court, 1927. Interim Rept. and statement of policy of Geol. Survey, by the Economic Geologist and Mineralogist; Brit. Guiana Combined Court, 1927. Rept. on the recent geological investigations in the Potaro River district, by H. J. C. Conolly and Smith Bracewell; Brit. Guiana Legislative Council, 1928. Rept. of the Diamond and Gold Industries Commission; Brit. Guiana Legislative Council, 1928.

Owing to the low prices obtainable for the diamond recovered and the great natural difficulties to be overcome, the development of diamond production in the country has been very slow. The proved diamantiferous area extends practically across the whole country in a belt some 10 to 30 miles wide, roughly 100 miles from and parallel to the coast.

Geologically, this tract of country consists mainly of a basement series of crystalline rocks covered by superficial deposits of sand and gravel, clay and laterite. The gravels are often diamantiferous, and are sometimes worked *in situ* when they occur as cappings of low hills, but most of the workings are in the valleys which have been cut in these deposits by numerous rivers and streams, since these are naturally richer. Immediately to the west lies the escarpment of the Pakaraima mountains consisting of a thick series of sandstone rocks.

Although diamond has been found over a wide area, the stones are obtained chiefly in five districts, named from the river valleys in which the workings are situated, the Mazaruni, Puruni, Potaro, Cuyuni and Berbice fields. All of them are situated in the midst of tropical jungle a long way from the coast, and are accessible only by boat.

In addition to these, diamond has also been found and worked in a small way in several localities in the valleys above the escarpment, especially above Kaieteur Falls, and the stones obtained from these have been above the average in size. The difficulties of access to these deposits, however, and the consequent cost of working them, coupled with the comparatively low price obtainable for the stones in recent years, have led to the suspension of work on these gravels.

The diamantiferous gravel varies somewhat in the different areas, but generally consists of quartz pebbles set in a sandy or clayey matrix, sometimes cemented with ferruginous material. It contains large and small boulders of country rock, chert and chalcedony, and quartz crystals, while the diamond concentrate obtained from it contains rutile, tourmaline, topaz, corundum, garnet, ilmenite, gold, etc. There is usually an overburden up to 5 feet thick, and the gravels, which vary considerably in depth, are often underlain by residual clays.

Often the gravels are quite thin, and in any case it is unremunerative to work deposits more than 25 feet deep by the hand methods employed in the country. The deposits vary in diamond content from complete barrenness up to 20 carats per cubic yard, but a concentration of more than 3 carats per cubic yard is unusual and most of the deposits do not yield 1 carat.

The method employed in recovering the diamond is very primitive. Gravel is dug from a small pit, mixed with water and hoed in a trough against a " tom-iron " with $\frac{5}{8}$-inch holes. The oversize is rejected and the undersize is jigged on a sieve usually having a mesh of $\frac{1}{16}$ inch. No account is taken of any diamond that may be present either in the oversize from the " tom " or in the sand which passes the sieves, but skilful operators probably recover 60 to 70 per cent. of the diamond in the gravel with their crude jigs. On the other hand there is a great tendency for roving diggers merely to pick over a deposit and pass on to another, so that there is probably a great deal of ground which would repay reworking if more efficient methods could be employed.

Although so long ago as 1902, hand-operated and steam-driven diamond-washing contrivances were put into operation on the Mazaruni field, these devices have not come into general use, partly because they have not always been suitable for the treatment of the gravels, but mainly on account of the difficulty of bringing gravel to the plant or of moving plant from place to place by boat. Nevertheless there has been a gradual increase in the number of mechanically operated pans and jigs employed. Rotary pans are now being successfully operated in the Upper Eping and Tacouba Creek areas.

The bulk of the stones are obtained by individuals working on their own behalf, mostly by West Indian negroes known locally as " pork-knockers ", while scattered throughout the diamond districts there are a number of shops (at present about 100), principally owned by Portuguese, at which the stones obtained by the diggers are sold or bartered for goods. There is no tendency to form townships; the camps and shops are all temporary structures, and the fields are patrolled by police.

It is very commonly the case that the shop owners are also the owners of diamond claims, which they allow the diggers to work on condition that all stones recovered are sold to the owner of the shop. This system naturally lends itself to abuse, but there are regulations designed for the prevention of theft by which all persons coming down the rivers are compelled to declare any stones in their possession. Whereas formerly the diamond buyers from overseas had their offices in Georgetown, most of them now have representatives on the diamond fields.

In 1926 a syndicate was formed in England called United Diamond Fields of British Guiana, Ltd., to purchase a number of these shops together with their claims, and generally to develop the industry on more scientific lines. They had an agreement by which the Diamond Syndicate (see p. 25) was to purchase their entire output. The Company did not handle more than about half the total output and was eventually wound up in 1928, most of the assets being taken over by the Bartica Co.

Prospecting licences, which are issued at a cost of \$5, entitle the owners to prospect and locate claims on Crown Lands for 12 months. A claim must not exceed 1,500 feet by 800 feet and the minimum annual rental is \$14. Occasionally exclusive permission is granted to explore and prospect over large areas for a period up to 3 years on payment of a fee of $10, and at a yearly rental of 7½ cents an acre. Firm title for mining is issued in the form of a Mining Concession or Claim Licence at a rental of 50 cents an acre. Holders of these may allow tributors holding a Mining Privilege (costing 1s.) to work their properties. A royalty of 50 cents per carat is charged on all stones recovered, and in addition there is an export tax of 35 cents per carat.

In the early days of the industry development was slow, and it was not until 1902 that the production reached 10,000 carats. The output remained at this level for 3 years and then declined until in 1907-8 it had fallen to about 2,000 carats. Then with minor fluctuations it steadily rose, and from 1913 to 1918 the average was between 20,000 and 30,000 carats, after which it rose very rapidly until 1923 when the peak of production was reached with more than 200,000 carats. Since then it has decreased steadily. The great increase subsequent to the war was largely due to the influx of numerous workers released from their military duties. The annual fluctuations are largely due to variations in weather conditions, for drought seriously curtails output.

The Mazaruni field has always been by far the greatest contributor to the output, and of recent years its quota has been about 90 per cent. of the total. Prior to 1924 the Puruni field held second place and the others were a long way behind, but in 1924 the discovery of rich ground in the vicinity of the Ewang River on the Potaro field led to a great migration of diggers to this field and the production rose from 2,000 carats to 25,000 carats, thus raising it to second place, which it has since continued to hold. In 1932 the Mazaruni and Potaro fields were the only producers of diamond.

Stones obtained from different localities vary considerably in size, form and quality, but all have suffered considerable attrition. The average size of stones declared for the whole country is about 6 to the carat. Each year a small number of stones exceeding 10 carats each is declared; the largest, which weighed 56 carats, was found in the Potaro district in 1926. The best quality stones come from the basin of Tacouba creek and from Eping, both in the Mazaruni field.

Regarding the future possibilities of the diamond fields and the probable source of the stones, very little exact information is available. At the present time prospecting is almost at a standstill, the shopkeeper-claimholders who were the pioneers having ceased to finance expeditions.

In their report to the Legislative Council (1928), the Commissioners appointed to look into the condition of the industry stated that they considered that in the circumstances the Government should estimate and map the diamond gravels and their concentrations in creeks, etc., and then cut trails and clear creeks to enable them to be reached and worked. This might show whether any deposits existed which could best be exploited by large-scale methods.

In 1925 a preliminary survey of the diamond fields was commenced, two geologists being appointed to carry out the work. Several reports appeared, but before the work was completed both the officers resigned and in 1929, owing to lack of funds, the Geological Survey was discontinued. A new party of surveyors has recently been formed, primarily to look for gold areas.

Whilst optimistic opinions have been expressed by those who base their views on the fact that diamond is known to occur over a wide area only a small portion of which has been depleted of diamond, it would appear that the better known and more easily worked areas are becoming gradually exhausted. No scientifically conducted searches for new diamond deposits have been made for several years and little is being done to work the known fields more efficiently or on a larger scale, but the government has recently constructed new roads and bridges in order to render the diamond fields more accessible and thereby stimulate activity in diamond mining in the Colony.

Little is known as to the origin of the diamond in the gravels. There appears to be reason for assuming that it has been derived from the sedimentary massif of the Pakaraimas, since the size of stones increases towards the escarpment, and those which have been found above it are also larger. The fact that diamond is won from diggings at the foot of the talus slopes, where the gravel consists of material which appears to have been derived from sandstone and conglomerate of the escarpment above, suggests that diamond may exist in some of these beds, but in spite of many searches diamond has not yet been found *in situ* in this sedimentary series. The sediments are intruded by numerous dykes and sills in places, and it may be that some of these have been the primary source of the stones, or again they may have been derived from the basement complex. No rocks comparable with the South African kimberlites have been found in the country.

Apart from diamond, no gemstone is found in economic quantity in the country.

British Guiana.—Exports of Diamond (Domestic Produce).

Year.	Quantity (carats).	Value (£).*
1928	136,490	524,758
1929	128,115	474,493
1930	104,756	298,201
1931	65,550	111,584
1932	57,069	112,779

* Converted at dollar = 4s. 2d.

Ceylon.*

Ceylon is an important producer of precious stones other than diamond, and is noted for the variety of gemstones which occur in the island. These include *sapphire* in several varieties, *ruby*, *chrysoberyl* in its various forms, *spinel*, *zircon*, *topaz*, *garnet*, *beryl*, *tourmaline*, *sphene*, *rutile*, *cordierite*, *sillimanite*, *andalusite*, *diopside*, *apatite*, many varieties of *quartz*, and the *moonstone* variety of orthoclase felspar. Practically all the gems are obtained from alluvial deposits in the present or former beds of streams in the south-western portion of the island.

The deposits have resulted from the denudation, under tropical conditions, of the Archaean schists, gneisses and crystalline dolomitic limestones which compose the southern half of the island, and which are presumed to be the primary source of the gemstones, the products being concentrated in the stream beds. The principal gemming localities are in the Balangoda, Rakwana and Ratnapura districts, which lie between Kandy and the south coast. In recent years most of the best sapphire has been obtained from Pelmadulla.

The gem-bearing gravel which is known as "illam" occurs in beds, patches or pockets, and may be found at any depth down to 120 feet, resting on the valley floor, so that the search for gems is a highly speculative operation. In some cases several layers of gem-gravel may be encountered at different depths, but the one resting on the valley floor is always considered to be the richest. The bulk of the gravel consists typically of rounded white quartz pebbles of all sizes, sometimes mixed with ferruginous concretions, sand, and organic matter, and it sometimes passes almost insensibly into the rock of the valley floor.

The gemming industry is carried on solely by the native Sinhalese, who sink pits in the paddy fields, extract the gravel in crude fashion and pile it in a heap. Washing is by hand and is carried out by means of baskets made of rattan, at the nearest stream where there is a sufficiently strong current. Very skilful handling of the baskets enables the washers to produce a heavy concentrate practically free from the lighter minerals. The gems are picked out by hand from the concentrate, and the remainder is thrown away. This residue frequently contains minerals of considerable scientific interest. In some places existing stream beds are dredged for gems by native methods, the principal rivers worked being the Niriella, Karawita Ganga and Getaheta Oya.

Much illicit gemming has gone on in the past and probably does so still. Ratnapura ("City of Gems") is the centre of the industry, and most of the cutting and polishing of gems is carried on there; Karawita is another important centre.

*** Ceylon Administration Repts., Pt. IV, 1903; 1904; 1905; 1906; 1907. A visit to the gem districts of Ceylon and Burma, by F. D. Adams; Bull. Canad. Inst. Min. Met., Feb. 1926, p. 213.**

Many differently coloured varieties of each gem are found, some being more highly prized than others, and hence artifices are often adopted with a view to improving the colour, and thus the value of stones. In particular many stones are heated, generally after having been encased in clay balls or other material; thus, for instance, rubies of purple tints are often greatly improved, while pale brown zircons are rendered colourless, and greenish zircons become yellow.

There is considerable confusion in the terms used in the Ceylon gem industry; thus, deep yellow corundum is known as " king topaz ", yellow sapphire is often called " oriental topaz ", white topaz is sometimes called " water sapphire ", bluish green topaz is sold as " aquamarine ", most of the stones sold as " green tourmaline " are zircon, and colourless zircon is called " Matura diamond ".

Ceylon *ruby* is generally of pale colour and not so valuable as that of Burma, and this also applies to the *sapphire*. Yellow, white, parti-coloured and star sapphire is not infrequently met with and the green variety is sometimes found. During 1927 and the early part of 1928 some exceptionally fine sapphire came to light, some of the stones being of such size and value that no market for them could be found until cut into smaller sizes. Ceylon *spinel* is commonly red, but a striking blue variety is also found, while the black spinel *pleonaste* (*ceylonite*) is not uncommon.

Ceylon is one of the principal sources of *chrysoberyl*, many of the stones being of the cloudy, chatoyant variety known to mineralogists as *cymophane*, but often called by jewellers " oriental cat's-eye " or " Ceylonese cat's-eye." It was at one time considered a fashionable stone. The dark green, strongly dichroic variety, *alexandrite*, found in the Ceylon gem gravels is often of very fine quality. This stone also sometimes exhibits chatoyance. *Beryl* is not common.

Topaz is common and is usually colourless, pale or dark yellow and sometimes green; the saffron-yellow variety known as " Indian topaz " is very rare.

Much of the world's supply of precious *zircon* comes from Ceylon, the stones being of almost all the hues met with in this gem, but stones of the true " hyacinth " variety are usually quite small.

The garnet from the gem gravels is mostly *hessonite* or " cinnamon-stone " of a warm yellowish red colour very similar to hyacinth. Hessonite is interesting because it exhibits a more fiery appearance by artificial light than by daylight. The red garnet *almandine* also occurs but in less abundance. On account of its similarity in colour to ruby it is sometimes known as " Ceylon ruby."

Tourmaline is abundant in the gem gravels, in fact the word itself is of Sinhalese origin. Most of the stones are brown, but yellowish-green ones are found, and as these somewhat resemble olivine they have been called " Ceylonese peridot."

Ceylon is the principal source of gem *cordierite*, the colour of which varies from light to dark blue. The light blue kind is sometimes known as "water sapphire," and the darker as "lynx sapphire," but cordierite is readily distinguished from sapphire by its very noticeable dichroism, lower hardness and specific gravity.

Amethyst pebbles occur in the gem gravels and are of superior quality. *Cat's-eye* (chatoyant quartz) is common, most of the stones being of greenish tints, while some are brownish red or yellow. It is often confused with cymophane; both are highly esteemed in the island and in India.

Moonstone pebbles occur in the gem gravels but the bulk of the Ceylon supply is obtained from peculiar adularia-bearing leptynite dykes in the Dumbara and Kandy districts of the Central Province, and at Weeragoda near Ambalangoda in the Southern Province. In addition to the common white moonstone, a blue variety is also obtained.

Garnet of the *almandine* variety has been obtained from hornblende-schist near Trincomalee, and *hessonite* from actinolite-gneiss near Point de Galle.

Official statistics of the production of precious stones in Ceylon are not published. It has been estimated that the annual value of the output is in the neighbourhood of £150,000, but this figure may well be wide of the mark seeing that the marketing of the stones is carried out privately and with great secrecy. No licensed sales are held, nor is any export tax levied. Statistics of exports are not divided into separate categories, and they take no account of those stones which go out of the country by post.

Ceylon.—Total Imports of Precious Stones.

Year.	Diamond.		Other Precious Stones (except pearl).
	Quantity (carats).	Value (£)	Value (£)
1928	3,309	33,170	9,860
1929	2,106	20,315	5,312
1930	900	12,052	7,937
1931	1,322	12,336	3,035
1932	1,031	7,846	2,425

Ceylon.—Exports of Precious Stones (except pearl and diamond.)

Year.	Domestic produce Value (£).	Re-exports Value (£).
1928	960	—
1929	1,288	—
1930	345	275
1931	22	11
1932	152	—

India.*

Diamond†.—Although it was so famous in bygone ages, the diamond industry of India has long since declined and is now mainly of historic interest. The country which from the earliest times up to 1725 had supplied the whole world with gems of the finest quality, and often of enormous size, now produces but a few hundred carats a year.

The localities where diamond is or has been produced are classified by Ball into three districts. The southern group lies in Madras and Hyderabad in the areas drained by the Penner, Kistna and the lower part of the Godavari rivers, the principal localities being Cuddapah, Anantapur, Bellary, Karnul, Kollur, Partial, and Golapilly. The eastern group lies in the valley of the Mahanadi river and its tributaries the Mand and the Ebe, with outliers in Chota Nagpur and in the Chanda district of the Central Provinces, the principal localities being Sambalpur, Hira Khund, Sonpur, Sumelpur and Wairagarh. The central group lies in the Bundelkhand district of the Central Provinces, and stretches from Panna eastwards towards Rewa and north-eastwards towards Allahabad. Except in this district all activities have long since ceased and the workings have been abandoned.

Diamond occurs in sandstones and conglomerates of the Purana group (presumed to be of pre-Cambrian age), known in the south as the Cuddapah and Karnul systems, and in the north as the Vindhyan system, and in alluvial and eluvial deposits derived therefrom.

In the southern area the workings appear to have been quite shallow and the diamantiferous bed less than a foot thick.

In the eastern area all the stones were alluvial.

In the central area where working still persists, the chief diamond-bearing bed, according to Vredenburg, is a thin conglomerate characterized by abundant jasper pebbles, lying above the upper Kaimur sandstone and below the Panna shales, while another diamantiferous conglomerate with abundant pebbles of vein quartz occurs above the Rewa sandstones and below the Bhander series. Stones are also found in detrital deposits derived from these rocks.

In the deeper workings, cylindrical pits from 18 to 35 feet wide are excavated by pick and shovel down to the conglomerate, which is too hard for the picks. Recourse is then had to treatment by fire followed by water, and cold chisels are used to excavate the rock

---

* Thanks are due to Dr. J. Coggin Brown for his criticisms and suggestions in connexion with this section.

† Manual of the Geology of India, by V. Ball, Part 3, Economic Geology; Calcutta, 1881, pp. 1–50. Geology of the State of Panna, principally with reference to the diamond-bearing deposits, by E. Vredenburg; Rec. Geol. Surv. India, 1906, 33, 261–311. A history of the Golconda diamond mines, by L. Munn; Journ. Hyderabad Geol. Survey, 1929, 1, 21–62.

which has been rendered fissile by heating. In some cases a primitive form of mining is carried on, short galleries being driven off from the shaft, which, after the conglomerate has been removed, are filled in with rubble.

The conglomerate is carried from the pit and broken up by means of sledge hammers to free the diamond from its matrix, mud and fine material is washed away, and the remainder spread out on a flat surface and carefully and repeatedly searched by hand for diamond, which, in spite of the rough treatment, is seldom broken. There appears to be no reference in the literature to any mechanical appliance whatever, not even a sieve, having been employed in any of the Indian diamond workings.

All the famous Indian stones appear to have come from the southern district, for which Golconda seems to have been the principal market. Among them may be mentioned the *Pitt* or *Regent* which is said to have weighed 410 carats when taken from the Partial deposits in 1701. It was subsequently cut, and the largest brilliant, which weighs 143·2 metric carats, and is one of the finest stones known, is now in the French national collection. The *Great Mogul*, seen by Tavernier in 1665 as a cut stone of $279\frac{9}{16}$ carats, is said to have weighed $787\frac{1}{2}$ carats in the rough and to have come from Kollur. It has been suggested that the *Orloff* (formerly in the Russian Crown Jewels) and the *Koh-i-noor* (in the British Crown Jewels) may both have been cut from this stone. The *Orloff* weighs 199·6 metric carats, and the *Koh-i-noor*, which in its Indian form weighed 191·09 metric carats, was re-cut for Queen Victoria into a brilliant of 108·83 metric carats. The *Florentine*, which is a clear yellowish rose-cut diamond in the form of a nine-rayed star of 137·25 metric carats, formerly in the Austrian Crown, is also an Indian stone. Two other famous gems of Indian origin are of interest on account of their colour, the *Hope Blue*, a beautiful brilliant weighing 45·5 metric carats, is of the very rare sapphire-blue colour, and the *Dresden Green*, preserved at Dresden, is an almond-shaped stone of 49·8 metric carats of a fine clear apple-green shade.

*Ruby, Sapphire and Spinel**.—The ruby mines of Burma have flourished since very early times, but here again the industry has seriously declined in recent years.

The principal locality for these gems is the Mogok area of the Kathe district. The ruby occurs with spinel in a series of lenticular bands of crystalline limestone, which form part of the Archaean complex extending from the bank of the Irrawaddy, through the Mogok Stone Tract, into the Mongmit State and beyond. The complex is a highly metamorphosed and strongly folded group of

* **The rubies of Burma and associated minerals, by C. Barrington and J. W. Judd; Phil. Trans. Roy. Soc., 1895, 187A, 151–228. A visit to the gem districts of Ceylon and Burma, by F. D. Adams; Bull. Canad. Inst. Min. Met., Feb. 1926, p. 213. Ruby mining in Upper Burma, by J. Coggin Brown; Mining Mag., 1933, 48, 329–340.**

garnet-biotite gneisses and garnetiferous granulites, invaded by acid gneisses, augite-syenites, pegmatites and ultrabasic rocks. The limestone itself cannot be profitably worked for gems, but the alluvium of the valleys, and the detritus on the hill sides, derived from the limestone, are the sources from which the stones are obtained.

The floor of the Mogok valley was probably occupied in former times by a lake, and the gems are obtained from a pebbly clay known as " byon ", the richest layer of which usually lies 15 to 20 feet below the surface, though sufficient gems often occurred in the lower horizons, down to the bed rock, to make their removal profitable, provided it could be done in large enough quantities. The limestone floor of the valley has been deeply incised by solution.

The Burmese kings worked these deposits for centuries and natives are still exploiting them, but operations on a larger scale commenced in 1889 when the Burma Ruby Mines, Ltd., were granted a lease of the " Stone Tract ". This company erected several washing plants at Mogok, Kathe and elsewhere.

The hand-dug material was loaded into trucks and hauled by endless ropeways to the washing plants, where, after preliminary screening to remove large pieces of rock and after passing through various screens and trommels, it was fed into circular pans with revolving arms, similar to the Kimberley diamond pans. The concentrates were sized again before going to the picking tables. The fines from the overflow went on to pulsators, which, in their turn, provided another product for the picking tables. Sorting on these was performed by Europeans or by natives, who, to prevent theft, wore boxes over their heads fitted with gauze windows. It has been authoritatively stated that an average daily turnover of 7,000 tons of earth in the mills of the company would yield good dividends, when an average value of 8 annas per ton was recovered.

A local custom known as *kanase* permits women to work without the payment of license fees to the Government, in tailings and dumps from mines and washeries, and to keep their finds, which are usually confined to tiny stones only suitable for watch jewels.

A more recent innovation is the use of monitor jets in breaking down the gravel, which is then raised by pumps, screened, and passed through special sluice boxes, the concentrates from which are treated in a pulsator. The concentrates from the mill are classified into grades by expert sorters.

In addition to *ruby* of various shades, the concentrate contains *sapphire* of various colours, *spinel*, usually pink and of characteristic octahedral form, common *corundum*, *tourmaline* (usually black and valueless, but sometimes of a fine blue colour), *zircon*, *quartz*, *beryl*, *garnet*, *chrysoberyl*, *topaz*, *peridot*, *scapolite*, *apatite* and rarely *sillimanite* which is sometimes of gem quality.

Owing to a number of causes, among which may be mentioned the dictates of fashion, the competition of artificial ruby, and the exhaustion of the richest deposits in the immediate vicinity of Mogok, the Burma Ruby Mines, Ltd., went into liquidation in 1925, but operations were carried on with varying success until 1931 when the mines were closed.

An extensive industry is, however, still carried on by the natives, who exploit the deposits by primitive methods, except that small power-driven pumps have recently been permitted for drainage purposes only. No one is allowed to mine unless he is registered on the lists kept by the authorities, of the descendants of the mining families at the time of the annexation of Upper Burma. The revenue of the Government is derived entirely from license fees paid by the miners and gives no indication of the value or the number of gems found in any particular period.

According to a report on the future of the ruby industry in Burma, J. Coggin Brown considers that the most hopeful possibilities lie in the large-scale treatment of the hill-side deposits*. He also remarks that, up to the present, the gravel has only been exploited in the Mogok, Kyatpyin, and Kathe valleys, and that other valleys such as the Kin and Khabine have not received the attention they deserve. The Stone Tract is seemingly by no means exhausted.

Sapphire, which is found in the byon in much less quantity than ruby, has never been found *in situ* in the crystalline limestone. It sometimes occurs intergrown with felspar and may come from veins of pegmatitic origin. It has also been found in nepheline syenite. In 1926 the Kyaungdwin mine, which had been a poor producer of ruby, suddenly became a rich producer of sapphire, the output exceeding £16,000 value that year, and early in 1927 two large stones worth about £7,000 were found there. Burmese sapphire is stated to be generally very dark in colour, yet the stones are often very beautiful, and of recent years have brought increasingly high prices in the market.

Ruby, *sapphire* and *spinel* have also been found in the Mandalay district near Sagyin and in the Myitkyina district near Naniazeik, but the output has been small, and no stones have been produced for many years. Occasional stones of gem value have been found in the corundum pits in the Salem district of Madras and in the Kadur district, Mysore.

Sapphire is obtained in Kashmir, where it occurs in association with *tourmaline*, *garnet*, *kyanite*, and *euclase* in a pegmatite vein on the southern slopes of the Zanskar range near Sumsam in the Padar district. For some years the Kashmir Durbar derived considerable revenue from these deposits as the sapphire obtained from the older workings was of the very finest quality.

* Burma ruby mines (Gen. Rept. Geol. Surv. India, for 1927); Rec. Geol. Surv. India, 1928, 61, 54.

Work was carried on in a desultory way until 1908, but in spite of the discovery of a new sapphire-bearing vein, the deposits were neglected until they came under the notice of the Kashmir Mineral Survey in 1924, with the result that the mines were re-opened and large stocks of uncut sapphire accumulated in the Jammu treasury.

The maximum production (in 1927) amounted to more than 450 kilos. of rough sapphire, and as an experiment, about 5 per cent. of this was cut locally by lapidaries from Delhi, who produced 501 stones weighing in all about 850 carats, the largest being a stone of 9 carats. The blue colour varied rather widely, but most of the stones were " of the deep and lively blue tint that is most appreciated by purchasers."*

Jadeite†.—This mineral, which is known to jewellers and to the general public as " jade," is obtained almost exclusively from mines and river terraces in the Mogaung subdivision of the Myitkyina district of Upper Burma. The stone has been produced since very ancient times and is very highly esteemed by Orientals, especially by the Chinese who value it above any other stone, no doubt partly on account of its supposed magical properties.

Formerly the whole production was from alluvial deposits, and part of the jadeite still comes from this source, but a quantity is being obtained from a pegmatite dyke. The alluvial jadeite, which is known as " Mawgyi jade," occurs as boulders at several localities in the alluvium on the hill sides, and in the stream beds. Mamon was formerly an important locality, but a larger quantity is now obtained from a tertiary conglomerate at Hweka, Pakhan and elsewhere.

The primary deposit crops out for a distance of 300 yards at Tawmaw and consists of an intrusion of jadeite-albite rock in serpentine, the dyke being bounded on one side by a margin of amphibolite, and on the other by a margin of chlorite. The line of strike is generally N.E.-S.W., and several other outcrops are known along it over a distance of some four miles. Much of the jadeite is white and marble-like but there are inclusions of the emerald-green variety (the colour being due to chromium), and in the upper part of the dyke the mauve variety was formerly obtained (the colour being due to manganese). There are two mines on the dyke; that of the Burchin Syndicate, and an old Chinese mine known as the Dwin Gyi, which is not worked and has partly fallen in.

The rock is extremely tough and difficult to excavate; former the Chinese employed fire to split it up, but this wasteful met

* Precious and semi-precious gemstones of Jammu and Kashmir, b Middlemiss; Jammu and Kashmir, Min. Surv. Rept. 9, 1931, pp. 4–5

† Rec. Geol. Surv. India, 1929, 62, 55. Rec. Geol. Survey India, 19 The mineral deposits of Burma, by G. de P. Cotter; Rangoon information kindly supplied by Mr. C. W. Chater.

has been superseded by drilling and blasting, the blocks being hoisted to the surface up a vertical shaft. Mining operations are only carried on in the dry season.

The jadeite comes from the mine in blocks of all sizes up to about half a ton, and even larger. It is hand picked and then scrubbed with cocoanut fibre, sand and limejuice. Each piece is then "mawed," which means that an area of about 1 inch by $1\frac{1}{2}$ inches is ground flat with a hand machine and polished in order to show its quality for the purpose of marketing.

The alluvial boulders include jadeite of any colour in the range, many shades of green, red, mauve, white, etc., but since the blocks are generally covered with a skin due to surface weathering, there is a considerable element of speculation as to what variety a block may contain even though it be "mawed."

The bright emerald-green jadeite is the most highly prized variety but mauve tints are also much esteemed; the duller greens and more opaque stones whose colour is due to iron rather than to chromium are not so valuable. All the dealers are Chinese and the value of any particular stone depends solely on the demand at the moment. Some of the stone leaves the country overland to Yünnan, to be worked up in Teng Yüeh, but the bulk is sent to Rangoon for shipment to China and the Straits Settlements

The Chinese have practised the cutting and carving of jadeite since prehistoric times and have attained a marvellous proficiency in the art, and although a quantity of carved ornaments of all kinds is sold in western countries, the best material never leaves China. A very small quantity is cut and carved in Mandalay.

The numerous trade varieties of Burmese jadeite, and their respective market values, have been discussed in a recent article by J. Coggin Brown.*

Jadeite producers have to pay taxes to Kachin chieftains on material extracted, and a further $33\frac{1}{3}$ per cent. to the Government, or to the licensee who has purchased the right to collect it for them. It has been pointed out that this system of farming out the tax lends itself to abuse.

Statistical information regarding the jadeite industry is rather unsatisfactory, for the mines lie in more or less unadministered territory, and official returns for production are approximate in rather a wide sense. For the quinquennial period ending 1929, the average annual quantity of jadestone exported by sea from Burma vas 2,107 cwt., and for the four preceding similar periods the nual average was about 4,600 cwt. These sea exports exclude the ntities crossing the land frontiers into China, as well as that med in Burma itself.

enite, a mineral of somewhat similar appearance to jadeite, ntally different character, has been used in some parts of

, by J. Coggin Brown; Rec. Geol. Surv. India, 1930, 64, 146–154.

India for making ornaments, knife-handles and the like. It is an apple-green to yellowish-white calcareous variety of serpentine occurring in slates in the upper Wardwan valley, and on the peak Mango-Gusor, near Shigar in Baltistan, Kashmir. Similar material occurs at Bamanvada in Idar State, and also in Afghanistan.

Other gemstones.—Many varieties of semi-precious stones occur in India and have from time to time been exploited.* Of these the most important is *agate* in its various forms. It is known under the general name "hakik," and is obtained from amygdales in the Deccan and Rajmahal traps, and from river gravels in the trap areas, especially from the rivers Kistna, Godavari, Bhima and Narbada, and from the State of Rajpipla at Ratanpur and Damlai, where it occurs in a Pliocene conglomerate.†

The agate is baked, for the purpose of improving the colour, at Limodra and sent to Cambay for cutting and polishing, and this latter place is the recognized centre of the industry, although some cutting is done at Jubbulpore, Banda and elsewhere. The Rajpipla mines were not worked from 1918 to 1928, and the peak of production was reached in 1915, when 508 tons were produced. In 1929, 148 cwt. were produced, and the mines were again closed.

Gem varieties of *beryl* occur at a few localities in India, particularly in the pegmatites worked for mica in Bihar and Nellore; at Padyur (Pattalai) near Kangayam in the Coimbatore district; in the Toda hills, Rajputana; and near Daso village in the Skardu Tehsil, Kashmir.‡ From the latter place, 3·75 cwt. were obtained in 1915, 4·13 cwt. in 1916, 20 lb. in 1920, and the last record was 55 lb. in 1921. In 1926 there was an output of 1,293 carats, valued at £7, from Ajmer-Merwara in Rajputana.

There has been some production of gem *garnet* in India, mainly from the mica-schists of Rajmahal in Jaipur State, the Sarwar district of Kishangarh State, and Ajmer-Merwara in Rajputana. The garnet is of the purplish red *almandine* variety, and the cutting of it for market has been an important industry in Jaipur and Delhi.

Since 1920, garnet has been obtained from Khammamet in the Warangal district of Hyderabad State.

The production of garnet in India has been, in 1913, 334 cwt.; in 1920, 407 cwt.; in 1921, 95 cwt.; and in 1923, 55·8 cwt., but these figures include other than gem varieties.

---

* Quinquennial Rev. Min. Prod., 1919–23; Rec. Geol. Surv. India, 1925, 351–358.

† Notes on Geology and Mineral Resources of Rájpiplá State, by P. N. Bose Geol. Surv India, 1908, 37, 176–182.

‡ Note on the aquamarine mines of Daso on the Braldu river, Shig Baltistan, by C. S. Middlemiss and L. J. Parshad; Rec. Geol. S 1918, 49, 161–172.

Several varieties of *tourmaline* have been worked in different parts of India, notably the beautiful red variety known as *rubellite*, which occurs in veins of decomposed granite at Maingnin, in Upper Burma. Production has not been recorded since 1907. A little has been found in the Northern Shan States. Green tourmaline has been worked at Namon near the Salween river in the Southern Shan States, and occurrences are known in the neighbourhood of the sapphire mines of Kashmir, and in some of the pegmatites of Hazaribagh which are worked for mica.

Peridot is obtained at Bernardmyo in the Mogok Stone Tract, and *lapis lazuli* from the Dattaw valley near Mogok.

Several varieties of *quartz* are produced for gem purposes. *Rock-crystal* is collected and cut for cheap jewellery in the Tanjore district, Madras Presidency, and is known as " Vallum diamond." The bipyramidal quartz crystals occurring in the gypsum of the salt-marl near Kalabagh and Mari, on the Indus, are known as " Mari diamonds," and are used in necklaces. Rock-crystal is also obtained from the Skardu Tehsil, Kashmir. At many places in the Deccan trap, geodes containing *amethyst* are worked, the bed of the Narbada river, near Jubbulpore, and the Sutlej valley in Bashahr, Punjab, being notable localities. *Rose-quartz* is found in many parts of India, particularly at Warangal in Hyderabad, and in the Chhindwara district.

Apatite of green colour is obtained from pegmatites at Ajmer in Rajputana, and a sea-green variety comes from Devada, Vizagapatam, Madras. Blue apatite occurs in the Mogok district of Burma.

Burmite, a variety of amber, occurs in the Tertiary clays of the Hukong valley in the Nangotaimaw hills, Myitkyina district, Burma, where it is associated with lignite. The Burmese sink pits up to 40 feet deep in a haphazard way, and pick out the amber by hand. Most of it goes to Mandalay to be made into beads and trinkets. Burmese amber is harder and denser than that from elsewhere. For the five years 1924-28 the average production amounted to 49 cwt. a year.

A number of other minerals are sometimes cut as gemstones in India. Among these are *kyanite*, from Narnaul, Patiala State, which also occurs in Kanaur and Bashahr in the Punjab Himalayas; *chrysoberyl*, which occurs near Kangayam in the Coimbatore dis-·ict and at Govindsagar, Kishangarh State, Rajputana; *cordierite*, ich is found in the hills of Vizagapatam and in the Kadavur ıindari, Trichinopoly district, Madras; *amazon-stone*, from ·nir and elsewhere; *hyacinth* (red zircon), which is found at Nath on the Ganges, and *rhodonite*, which is a common ·7 mineral at some of the manganese mines of the Central

*India.—Production of Ruby, Sapphire, Spinel and Jadeite.**

Year.	Ruby (carats).	Sapphire (carats).	Spinel (carats).	Jadeite (cwt.)
1913	203,925	21,353	53,428	3,281
1919	88,847	47,286	22,444	3,821†
1920	88,491	33,015	34,098	5,094†
1921	112,197	48,916	32,802	5,374†
1922	93,078	102,462	35,620	5,762†
1923	92,592	65,692	28,726	3,088†
1924	53,512	37,942	9,644	2,630
1925	109,998	31,508	7,531	1,697
1926	65,226	31,221	9,124	1,204
1927	35,230	2,890	1,470	2,227
1928	32,010	4,500	3,870	2,845
1929	37,640	2,530	3,480	3,451
1930	25,720	1,586	2,784	1,499
1931	12,000‡	100‡	—	2,765
1932	30,090§	—	—	1,499

* The figures for production of ruby, sapphire and spinel are those of Burma Ruby Mines Ltd., and take no account of the large native industry.
† Exports by land and sea.
‡ Estimated.
§ Includes sapphire and spinel.

British India.—Total Imports of Precious Stones.

Year.	Diamond Value (£).	Other Precious Stones (except pearls) Value (£).
1928	654,259	72,579
1929	654,413	14,437
1930	377,936	33,753
1931	304,529	11,821
1932	428,855	9,930

Australia.

Diamond.—While diamond is undoubtedly widely distributed in alluvial deposits in New South Wales, and a few stones have been found in Queensland, Victoria and Tasmania, no extensive field has ever been discovered.

In New South Wales,|| most of the finds have been made while washing for gold and sometimes for tin, but very few stones have been won in recent years. The most productive areas have been in the Bingara, Inverell, Bathurst, Mudgee and Tingha divisions, but recently almost the whole output has come from the Copeton workings in the Tingha division.

In 1904, a discovery of considerable scientific interest was made at Oakey Creek, near Inverell. This was the finding of a diamond

|| Mineral Resources of New South Wales, by E. F. Pittman; Geol. Surv., Sydney 1901. Mineral Industry of New South Wales, by E. C. Andrews and staff; Dept. Mines, Sydney, 1928. The diamond deposits of Copeton, New South Wales, by L. A. Cotton; Proc. Linnean Soc. New South Wales, 1914, 39 803–838.

crystal firmly embedded in an igneous rock, described by T. W. Edgeworth David* as hornblende-diabase. The rock, which is a dyke intruded into granite, has been described by Cotton as quartz-dolerite, and by Thomson† as dolerite. At least one other diamond crystal was obtained subsequently from decomposed portions of the same dyke.

Rocks described as volcanic breccias, somewhat similar to the South African pipes, occur at Ruby Hill about 12 miles south of Bingara, in the county of Murchison, and at Snodgrass, 20 miles west of Delegate.

In Queensland, diamond of greenish colour is occasionally met with in the tin wash on the Stanthorpe field. Small yellowish stones have been found while washing for gold in the Woolshed valley, Beechworth, Victoria, and also in the neighbourhood of Mt. Donaldson, near Corinna, Tasmania. In general it may be said that Australian diamond is of excellent quality.

Ruby and sapphire.—Sapphire is widely distributed in New South Wales in Tertiary and recent alluvial deposits, but it is generally of too poor a colour for gem purposes. In the Inverell district, however, sapphire of gem quality, together with much that is of use only for industrial purposes, occurs in the surface soil and in recent alluvial accumulations, accompanied by pleonaste. A dredge is in operation on these deposits, sapphire being recovered by means of sluice boxes and a pulsator. Stones weighing 40 carats have been obtained, and 10 per cent. of the marketable gems produced exceed one carat in weight.

In Queensland, the sapphire-mining industry has been of greater importance, but although there have been isolated finds in a large number of different parts of the State, the only field where commercial supplies are obtained is at Anakie.‡ The stones occur in old alluvial deposits stretching over an area of about 20 square miles, and were first discovered in 1870. The deposits lie along the banks of creeks, very rarely in the present stream beds, and generally parallel to but high above them. There are four main localities, Retreat Creek, Policeman Creek, Tomahawk Creek, and Central Creek, and several minor ones.

The wash varies greatly in thickness in different places, reaching perhaps 50 feet in Tomahawk Creek; sometimes it is clayey and sometimes loose and friable, but there is generally a reddish clay below, resting on the bed-rock. Sapphire is irregularly distributed through the wash, very rich pockets being sometimes encountered. Stones of blue, green, yellow, purple and other shades are found, and sometimes parti-coloured stones, and an occasional

---

* Compte Rendu, Congr. geol. internat., Mexico, 1906, pp. 1201–1210.

† J. A. Thomson; Geol. Mag., 1909, 6 (new ser.), 492–497.

‡ Report on the sapphire fields of Anakie, by B. Dunstan; Brisbane, 1902.

ruby; blue sapphire predominates at Retreat Creek and Policeman Creek, and green elsewhere.

The method of recovering the stones varies somewhat according to the kind of wash in which they occur, and also according to the scarcity of water in the locality. A good deal of the work is accomplished with simple hand sieves and by hand-picking. Sluice boxes are not often used on account of insufficiency of water.

In addition to stones for gem purposes, a quantity of corundum has been produced for use in bearings or pivots for scientific instruments and watches as well as for abrasive purposes.

The industry has been subject to great fluctuations in prosperity; in 1913 the population of the field was about 840, and the production valued at £43,292. Then came the war when operations almost ceased, the population in 1915 being 275, and the output worth only £600. A revival then commenced, which approached a boom in 1919 and 1920, and in the latter year some 2,000 persons were engaged in the industry, the output being valued at £65,831. This position was not maintained; the output value fell, at first gradually, and then in 1926 it suddenly went down to £6,799 and in 1927 to £2,202. There has since been some recovery.

A system which had been inaugurated in 1921, whereby the State acquired the produce of the sapphire field and marketed it, was abandoned as from 1st June 1928, when private buying recommenced.

Many of the stones produced in New South Wales and Queensland are cut and polished locally.

Opal.—Precious opal is the most important gemstone produced in Australia, from whose opal fields comes the bulk of the world's supplies. New South Wales, Queensland and South Australia all contribute to the output, and an occurrence of fire-opal is known at Yundamindera in Western Australia.

In New South Wales,* opal occurs in the Tintenbar district, near Ballina on the Richmond river, as loose pieces in the soil, and as a cavity filling in decomposed vesicular basalt of Tertiary age. In the White Cliffs district, in the county of Yungnulgra, some 65 miles N.N.W. of Wilcannia, and in the Lightning Ridge district, about 47 miles N.N.W. of Walgett, which includes the Grawin field, precious opal occurs in sandy sediments of Cretaceous age.

The precious opal occurs as thin bands and seams, along joints and small fault planes, and in nodules, at all depths down to about 100 feet, in sandstones and shales, which are usually capped by pudding-stone conglomerate and quartzite. Occurrences of the latter type are of greater commercial importance, Lightning Ridge and Grawin being the most productive fields.

---

* **Mineral Industry of New South Wales, *op. cit.* Grawin opal field, New South Wales; Chem. Eng. Min. Rev., 1927, 19, 412.**

Both " white " and " black " opals are produced, but the latter are more uncommon and very highly esteemed. Black opal is a comparatively new gemstone which first came to light in 1903; the Lightning Ridge field is the chief producing locality for this type.

In Queensland,* precious opal occurs under similar conditions, most of the deposits lying close to the surface in beds of sandstone and clay-ironstone belonging to the Desert Sandstone Series. It has also been found in decomposed trachytic and basaltic rocks at Springsure. A very large area in western Queensland is known to be opal-bearing, but the chief centres of production have been Kynuna near Winton, Opalton and Fermoy in the Longreach district, Eromanga, and Yowah near Thargomindah. Black opal is found near Hungerford, close to the southern boundary. The opal-mining industry in Queensland has greatly declined since the war.

In South Australia,† precious opal was discovered in 1915, in the middle of Stuart's Range, about 70 miles west of Anna Creek Station, in a very arid region. Here also it occurs in irregular veins and patches in sandstone and claystone of Upper Cretaceous age. Production commenced in 1916 and rapidly grew.

The district, which is now known as the Coober Pedy opal field, is of considerable extent, stones having been found over a distance of 40 miles. The opal is of the " white " variety similar to that produced in New South Wales at White Cliffs and is associated with gypsum and sometimes with alunite. As the opal field is situated in country almost devoid of water, the activities depend to a large extent on rainfall. During the years 1919 and 1920, when production reached its maximum, some 200 men were employed on this field but the maximum number now employed is less than 100. The great falling off in output in 1921 was due to the general slump in world trade.

In 1931 a new opal discovery was made 15 miles south-west of Mount Johns, which is 130 miles north-west of Oodnadatta. The opal, which has been traced over a distance of six miles, is stated to be of a darker shade than that of Coober Pedy.

Emerald and beryl.—Emerald of gem quality occurs in beryl-bearing mica-schist, and in pegmatites, in the vicinity of Poona, some 40 miles north-west of Cue, Western Australia.‡ A company acquired leases in 1926 and commenced production the following year. The output was 200 carats of cut stones valued at £421 in 1927, 17,564 carats of uncut stones valued at £910 in 1928, 609 carats of cut and uncut stones valued at £278 in 1929. There was no production during the years 1930-1932. Attempts have also

---

* **Mining Mag., 1922, 26, 275.**

† **S. Aust. Min. Review No. 25, 1916, and No. 34, 1921.**

‡ **The beryl deposits of Poona and Ferndale, by R. C. Wilson; Rept. Dept. Mines, W. Australia, 1925, Appendix 3, p. 81.**

been made from time to time to work a pegmatite dyke for emerald at Emmaville, New South Wales.

Beryl occurs at several localities in Australia, often in association with cassiterite, but none is known to be of gem quality. In South Australia there are deposits of common beryl, near Olary, small quantities of which have been sent to England and Germany for experimental work in connection with the production of beryllium.

Other gemstones.—In washing for sapphire a small number of other stones are sometimes recovered. These include *zircon, garnet, spinel* and *topaz.*

Crystals of *rhodonite* and *spessartine* occur in the Broken Hill lode, while many varieties of *quartz* and *agate* occur in numerous localities, but there is no trade in these stones.

The use of *alunite* as an ornamental stone has been suggested; the pink variety looks well when cut.

Thin seams of *turquoise* of unsatisfactory colour occur at Wagonga on the south coast of New South Wales.

Pale coloured *peridot* and yellowish *chrysolite* are found in the basalt of the Toowoomba Range in Queensland. A number of these stones were obtained, about the year 1910, from near Spring Bluff station, near Harlaxton, the Wallaby Rocks on the Peninsula and the base of One-tree Hill, but there seems to have been little further production.

Australia.—Production of Opal etc.

Value (£).

Year.	Opal.			Other gemstones chiefly sapphire.
	New South Wales.	South Australia.	Queensland.	Queensland.
1913	29,493	—	3,000	43,292
1919	27,552	20,000	600	42,883
1920	23,600	24,000	500	65,831
1921	13,020	7,000	500	46,524
1922	15,150	5,500	500	35,362
1923	3,040	3,500	500	23,309
1924	10,500	4,000	300	24,340
1925	10,030	9,070	1,000	34,573
1926	11,485	10,330	600	6,799
1927	13,353	9,157	400	2,202
1928	11,000	11,540	600	4,130
1929	6,071	11,056	600	4,810
1930	5,500	1,142	800	4,948
1931	2,178	3,127	600	2,9[illegible]
1932	1,233	3,060	500	1[illegible]

Australia.—Imports and Exports of Precious Stones.

Year ended June 30.	Total Imports Diamond Value (£).	Exports (Domestic Produce) Opal Value (£).
1928	533,351	9,162
1929	518,130	13,374
1930	251,434	48,589
1931	22,899	16,121
1932	49,032	21,254

New Zealand.

Deep green *nephrite* variously known as "greenstone," "jade," "axe-stone," and by the Maoris as "pounamu," is found in the form of pebbles and boulders in the glacial débris of many of the valleys of North Westland, chiefly in those of the Arahura and Taramakau rivers, as well as in the gold-sluicing claims of the Kumara district. It has been found *in situ* in the form of rounded segregations up to two feet across, in talc and talc-serpentine rocks in the Griffin Range.

Nephrite has been used by the natives of New Zealand for weapons and ornaments since very early times. It is still cut and polished locally, and some is sent abroad for cutting into small ornaments.

Agate is found in some abundance in the Mount Somers district of Canterbury, and it also occurs in the Hauraki Peninsula, while *precious opal* has been found in rhyolite in the Tairua district of the same area.

South Georgia.*

The mineralogist who accompanied the "Quest" expedition reported that there was a diamantiferous deposit on one of the islands of the South Georgia group. It has since been stated that a Cape Town fishing company has made a further investigation and has found *diamond*.

* Mining Mag., 1922, 27, 8.

GEMSTONES IN FOREIGN COUNTRIES.

Austria.

The occurrence of *emerald* in mica-schist at a very inaccessible spot on the east slope of the Legbach ravine, a branch of the Habachthal, in Salzburg, has been known since the time of the Romans. Stones have been produced intermittently but the occurrence is of little importance.

Amethyst, almandine garnet and bottle-green *diopside* have been obtained from the Zillerthal in the Tyrol and cut for gem purposes.

Belgium.

While Belgium is not a producer of precious stones it is one of the principal centres of the diamond-cutting industry, and the trade in diamonds is therefore of considerable dimensions. The official returns published, however, are not particularly comprehensive.

Belgium-Luxemburg E.U.—Exports of Precious Stones.

Year.	Rough Value (£1,000).	Cut Value (£1,000).
1928	706	12,888
1929	791	11,036
1930	603	5,613
1931	1,356	7,062
1932	1,719	3,847

Czechoslovakia.

The occurrence of *pyrope* or " Bohemian garnet " near Trebnitz in the north-east of Bohemia was formerly of considerable importance and gave rise to a large local cutting industry.* The garnet occurs in Pleistocene drift around Chodolitz, Podseditz, Třiblitz, etc.; in Tertiary conglomerates at Meronitz; in volcanic breccias and tuffs associated with Tertiary basaltic flows near Starrey; and in various alluvial deposits derived from one or other of these beds, the whole garnetiferous district extending over an area of some 27 square miles. The stones seldom exhibit their crystalline form but are of exceptional purity and very free from flaws. The Bohemian garnet industry received a severe setback when large numbers of " Cape rubies " became available as a by-product of diamond winning in South Africa, and finally, when fashion decreed that garnet should no longer figure prominently as a gem, the Bohemian industry became practically extinct.

* Die böhmischen Granatlagerstätten, by H. Oehmichen; Zeits. f. prakt. Geol., 1900, 8, 1-13. Das Granatenbergel bei Meronitz und die "böhmischen Granaten," by J. E. Hibsch; Bilin (Museumsgesellschaft), 1926, 20 pp.

Sapphire suitable for cutting was formerly obtained from the Iserwiese district, where it occurred with zircon in loose alluvial material derived from the weathering of granite. The stones were often of fine quality but always small, and the deposits have long been exhausted. Sapphire was also obtained from the garnetiferous sands of Meronitz.

Peridot of gem quality is occasionally found in the basalt of Mt. Kosakov, near Semil on the Iser, and the same rock contains amygdales of agate, carnelian, jasper, etc. There are several occurrences of the latter stones in the basaltic rocks of northern Bohemia, and they are often found as pebbles in the rivers Iser and Elbe.

In north-eastern Czechoslovakia there are important *opal* deposits. Formerly this territory was part of Hungary and the stone is always known as "Hungarian opal." The opal mines, which are of considerable age, lie to the east of Eperies (Prešov), the chief localities being Mount Simonka and Mount Libanka. The precious opal occurs in crevices in mica-hornblende-andesite and pyroxene-andesite, and is accompanied by common opal, marcasite, pyrite, stibnite and barytes. Hot springs are found in the vicinity. In "Hungarian opal" the colour is irregularly distributed in small patches, and although very beautiful, large pieces are now very uncommon. The annual production is probably about 2 or 3 thousand carats.

France.

Small crystals of gem-quality *zircon* both of the *hyacinth* variety and flame-red stones, weathered out from the basaltic tuffs of the district, are found in the beds of the Riou Pezzouliou and other small streams in the vicinity of Espaly (Expailly) in Haute-Loire.

Variscite or *bone-turquoise* occurs in some abundance in Miocene beds at Simorre and Auch in Gers. It is the fossil remains of mastodon teeth.

Rock crystal was at one time obtained in some quantity from druses in the French Alps, notably at La Gardette near Bourg d'Oisans in Isère, the stones when cut being known as "Briançon diamonds". Pebbles of quartz from Médoc and Alençon in Normandy were also formerly cut and known as "Alençon diamond". *Amethyst* is obtained near Clermont in the Auvergne, and *citrine* was formerly obtained from Bourg d'Oisans.

The cutting of semi-precious stones is carried on at Royat (Auvergne), better-class stones being cut at St. Claude (Jura).

France.—Exports of Precious Stones (Domestic Produce).

Value (£).

Year.	Gemstones of all sorts, crude or cut.	Agates, crude.	Agates, worked.
1928 ...	4,354,800	3,800	5,000
1929 ...	4,720,800	1,000	1,300
1930 ...	3,643,500	500	2,700
1931 ...	2,065,900	100	1,400
1932 ...	1,917,000	30	100

France.—Imports (for consumption).

Value (£).

Year.	Gemstones of all sorts, crude or cut.	Agates, crude.	Agates, worked.
1928 ...	7,020,200	7,300	215,800
1929 ...	7,903,900	3,400	50,900
1930 ...	3,752, 00	1,000	48,400
1931 ...	1,992,000	700	34,900
1932 ...	1,624,000	300	15,700

Germany.

Topaz of a pale wine-yellow colour occurs at Schneckenstein near Auerbach in eastern Vogtland, Saxony. It was a famous source of this gemstone in the 18th century, but the deposit has not been worked for many years. Some of the topaz is of a greenish yellow colour and has been called " Saxon chrysolite ".

Amethyst from amygdaloidal rocks near Oberstein on the Nahe was formerly well known, but is now exhausted. *Chrysoprase* is obtained from several places in the vicinity of Frankenstein south of Breslau in Prussian Silesia where it occurs as veins in serpentine.

Idar and Oberstein on the Nahe are the world's principal centres of the semi-precious stone cutting industry, which commenced simply as an agate-cutting industry, and this in turn arose by reason of the occurrence in this district of *agate* of fine quality in relative abundance. At the present time, however, practically all the local material has been exhausted and the cutters rely entirely on stones imported from abroad, mainly from Brazil, Uruguay, India and South-West Africa.

Fluorspar occurs at many localities in the Saxon Erzgebirge, yellow shades predominating.

Netherlands.

Although producing no precious stones, the Netherlands is a very important centre of the diamond-cutting industry. The following table shows the recorded exports to the United States, which are said to represent 60 per cent. of the country's exports.

Netherlands.—Exports of Diamond to the United States.

Year.	Cut.		Rough.		Industrial.	
	Quantity (carats)	Value (£)	Quantity (carats)	Value (£)	Quantity (carats)	Value (£)
1928 ...	209,305	4,606,800	57,173	203,400	24,960	49,100
1929 ...	176,162	3,883,100	124,713	200,500	9,535	23,100
1930 ...	110,237	1,937,500	65,722	77,700	4,719	2,700
1931 ...	59,959	869,800	112,639	187,200	2,024	12,500
1932 ...	40,654	529,000	(*a*)	(*a*)	(*a*)	(*a*)

(*a*) Information not available.

Norway.

Emerald of poor quality occurs in granite at Eidsvold, at the southern end of Mjösen lake, while Tvedestrand and Hiterö on the south coast of Norway are famous localities for *sunstone* (felspar), which occurs as irregular masses in veins of white quartz traversing gneiss.

Beryl suitable for cutting has been obtained from a pegmatite vein on the southern side of Fykanvatn, at the head of Glåmfjord.

Spain.

In 1870 *diamond* was reported to occur in the bed of a stream near Carratraca in Málaga, and the report has been confirmed within the last few years.* A considerable number of very small stones, none of which exceeded one millimetre in diameter, were found in the gravels of several streams, especially in the Cañada Honda, but the occurrence is not one of commercial importance. The rocks through which the streams have cut their valleys are peridotites and the diamond occurs in the vicinity of nickel mines.

Amethyst and other varieties of *quartz* suitable for cutting occur near Carthagena in Murcia and near Vich in Catalonia. Yellow quartz known as " Spanish topaz " or " false topaz " is found as pockets in veins of white quartz traversing granitic rocks in Salamanca Province. The Amistad mine near Villasbuenas was

* La zona diamantífera de Carratraca (Málaga), by E. Rubio; Bol. Inst. Geol. y Min. de España, 1927, 49, 249–265.

an important source of these stones, but in recent years activities have been confined to the working over of old dumps. From Hinojosa in Córdoba quartz has been obtained which assumes a fine yellow colour on heating and then passes for topaz.

Haematite from the iron mines near Bilbao and Santiago de Compostela in northern Spain has been used for gem purposes.

Jet is worked at Oles and elsewhere in the vicinity of Villaviciosa in Asturias and some of it comes to Whitby in Yorkshire for cutting. There are also occurrences at Utrillas and Gargallo in Aragón.

Switzerland.

Although isolated occurrences of a few semi-precious stones such as *hessonite garnet*, colourless *tourmaline* and *adularia* have been recorded, the only stones of any economic value found in the country are *rock crystal* and *smoky quartz*.

The former occurs in drusy cavities of rocks on many of the Alpine peaks, often in very inaccessible spots. Several hundredweights of very fine crystals have, however, occasionally been obtained from one cavity, and the crystals sometimes reach considerable size. A famous find of smoky quartz was made in 1868, in a cave in weathered granite near the Tiefen glacier in Canton Uri, from which more than 300 cwt. of fine crystals were removed.

U.S.S.R. (Russia).*

Diamond has been found in several gold- and platinum-bearing alluvial deposits in the Ural Mountains but the occurrence is of no economic importance.

Emerald, the most important gemstone produced in Russia, occurs in the Ural Mountains, the emerald mines being on the Takovaya, about 57 miles east of Ekaterinburg (Sverdlovsk). Emerald occurs here in mica-schist interfoliated with talc- and chlorite-schist, and is accompanied by *beryl*, *phenakite* and *chrysoberyl*. The stones produced are of good colour and sometimes of considerable size, but inclusions of mica are common and good stones are very rare. The pits are about 150 feet deep.

In 1927 it was reported that a firm of jewellers in New York had secured a concession covering the sale of Ural emerald, the mines to be equipped with American machinery and the stones transported by air to Paris.

---

* Die Schmuck- und Edelsteine der Sowjetrepubliken, by A. Fersmann; Zeits. f. prakt. Geol., 1929, 37, 209–216. Ann. Rept. Min. Res. U.S.S.R. 1926–27, Geol. Committee, Leningrad, 1928 (in Russian), pp. 1062–1070. Precious and ornamental stones of Russia, by S. E. Lavrov; Econ. Geol., 1931, 26, 432–436.

Statistics of production only indicate the output of emerald-bearing schist in cubic metres, but it has been estimated that since 1830 some 36,000 lbs. of emerald has been produced from the Ural emerald mines, of which only about 220 lb. has been suitable for cutting. The yearly output is stated to be about 100,000 carats of material suitable for cutting, and the reserves have been estimated at 10 million carats.

Chrysoberyl (*alexandrite*) is produced from the same mines to the extent of about one per cent. of the emerald, and *phenakite* to the extent of about five per cent.

Beryl of gem quality occurs at several localities in the Urals, but principally near Mursinsk, where many very fine stones have been produced. The beryl, which shows a considerable range in colour, occurs here in coarse-grained granite and is accompanied by *topaz* and *amethyst*, both of which are also worked.

Tourmaline, mostly of the rubellite variety, is said to be produced to the extent of some 8,000 carats a year at the Lipovskaya mine in the Urals.

Demantoid garnet (erroneously known as " olivine ") is a very beautiful grass-green stone found in economic quantity only at Nizhne-Tagil in the Sissertsk district of the Urals, where it occurs in serpentine. An emerald-green chromiferous variety of garnet is sometimes confusingly referred to as " Uralian emerald ".

There are important deposits of *jasper* in the southern Urals in the vicinity of Troitsk and Verkhne Uralsk.

Numerous other semi-precious and ornamental stones have been obtained from the Urals, including *quartz* in great variety, *rhodonite*, *euclase*, *amazon stone* and *labradorite*.

Chalcedony suitable for staining is collected on the seashore in the Crimea near the Karadagh Mts.

Onyx-marble occurs in extensive deposits near Ahalzih in Armenia.

Labradorite is worked in the Ukraine, especially near Gorodishch and in the Zhirtomir district. It occurs in several varieties, and is obtained in large blocks.

A certain amount of cutting and polishing, especially of semi-precious stones, is done in the country, notably at works at Sverdlovsk in the Urals and at Peterhof near Leningrad. It also constitutes a home industry in several parts of the country, generally near the producing localities. Only the cheaper stones are retained in Russia, there being no demand under existing circumstances for the better-class gemstones.

There are numerous occurrences of semi-precious stones in Asiatic Russia but the available information concerning them is very meagre.*

In the Uzbek Republic a number of occurrences of *turquoise* are known, especially near the Kansaisk lead mines, near Kuraminsk, and in the Karatube mountains.

Dark green *nephrite* occurs south of Irkutsk in the Baikal region. The primary source lies probably in the Sayan mountains west of Lake Baikal, but the material collected is that occurring as loose boulders brought down by the rivers Bielaya, Kitoi, Bistraya, Sludyanka and Onot.

The same region produces *lapis lazuli*, the principal deposit being in a white dolomitic limestone close to the Little Bistraya river west of the lake.

Riband-jasper is said to occur at Okhotsk in Eastern Siberia together with an ornamental variety of *obsidian*, and *jasper* is cut and polished in considerable quantity at the Kolyvan Stone Works in Altai and at Revnevski. *Avanturine* is found at Beloretzkaya near Kolyvan. A deep blue variety of chalcedony obtained at Nerchinsk is known as " sapphirine."

Beryl occurs abundantly in the Altai Mts., but is chiefly of the common variety. The gem variety is obtained in the Nerchinsk district of Transbaikalia, especially in the Adun-Chalon range with its southern extension, the Kuchuserken mountains, and also in the vicinity of the Urulga river on the northern side of the Borshchovochnoi mountains. The Adun-Chalon deposits have produced very large quantities of *aquamarine* together with *topaz*, *smoky quartz* and some red *tourmaline*. In this locality the beryl is mainly of the aquamarine colour. It occurs in topaz-rock and the prism faces of the crystals are frequently deeply striated parallel to the long axis. In the Urulga deposits the beryl crystals, which are mostly of a yellowish-green colour, are generally smooth and remarkably large and fine.

The brownish-green garnet *grossular* occurs in fine crystals in the Vilui river.

Among other stones which have been worked in Asiatic Russia for gem purposes may be mentioned *dioptase*, an emerald-green hydrous silicate of copper, from Altyntube; *hemimorphite*, a hydrous silicate of zinc, resembling turquoise, from Nerchinsk, and *sunstone* (felspar) from Verkhne Udinsk, on the Selenga river near Lake Baikal.

Russian exports are recorded only as total rough stones; they amounted in 1926-1927 to 1,500 and in 1927-1928 to 1,800 kilos, most of which went to Great Britain.

Imports into Russia consist mainly of stones used for industrial purposes, chiefly diamond.

*** Siberia, its resources and possibilities, by B. Baievsky; U.S. Dept. Commerce, Trade Promotion Ser. No. 36, 1926, p. 45.**

Angola.*

Diamond.—The diamond fields of Angola are a continuation of the Belgian Congo fields, and were discovered as a result of the opening up of the latter by the Forminière (see Belgian Congo, p. 89). The worked deposits lie in the Lunda district in the north-east of the country close to the boundary, the principal area covering about 6,000 acres in the northern part of the district bounded by the Tshikapa and Kasai rivers. Mining operations are, until 1951, in the hands of the Companhia de Diamantes de Angola (abbreviated into " Diamang "), which was brought into existence as an offshoot of the Forminière and commenced operations in 1916. Its headquarters are at Dundo and work is in progress at more than twenty localities in the district.

The deposits are similar to those in the Belgian Congo, both creek and terrace types being worked. Overburden of ½ to 2 yards has first to be removed before reaching the diamond gravel which seldom exceeds 1 yard in thickness. The gravel contains besides quartz, staurolite, kyanite, ilmenite, tourmaline, chrysoberyl and garnet, and the diamond content varies in different places from a small fraction of a carat to several carats per cubic metre.

The diamond content of the gravels, which averaged 1·25 carats per cubic metre in 1924, had dropped to 0·9 carats in 1929.†

Until 1923 the equipment employed in recovering diamond consisted mainly of rocking screens and Joplin jigs scattered over the various deposits. These were gradually replaced by four semi-mobile mills operated by electric power, and in 1925, owing to the increase of theft, the milling circuit was locked from the point where the gravel from the pit entered the mill. In order still further to increase efficiency and reduce losses by theft to a minimum, a single picking station was ultimately constructed in 1929 near the centre of the field to handle the concentrate obtained at the four mills.

The equipment of the mills consists of a cylindrical trommel with 25 mm. openings, the oversize from which is hand sorted, two rotary pans 8 feet in diameter in which the under-size from the trommel is concentrated successively, a second trommel which sizes the concentrate into three grades, and a series of Harz jigs, the hutch product of which constitutes the final concentrate. This is collected by van and taken to the central picking station where a magnetic separator, several Harz jigs, and a grease table for treating the larger size concentrate, are installed. The final product is

---

* The Angola diamond fields ; S. Afr. Min. Eng. Journ., 1923, 33, 633. The Congo-Angola diamond fields, by S. H. Ball ; Mining Mag., 1925, 33, 118 (abstr. from the Jeweler's Circular, New York). Mechanizing operations reduces theft of diamonds in Central Africa, by L. J. Parkinson ; Eng. Min. World, 1930, 1, 127–130. Also information supplied by the Diamang Company.

† Annales des Mines, Paris, 1931, No. 8, p. 132.

hand picked. About 35,000 cubic metres of gravel can be handled per month.

The stones produced are small but of good quality, the proportion of bort being low. The average size is 8 or 9 to the carat. Like that of the Belgian Congo, the diamond production of Angola has greatly expanded in recent years and now exceeds 300,000 carats. The Diamang sales are handled by the Diamond Corporation through the Anglo-American Corporation.

Angola.—Exports of Diamond (Domestic Produce).

Year.	Quantity (carats).	Value (£).
1928	232,256	447,100
1929	311,199	644,500
1930	318,634	691,100
1931	357,525	599,000
1932	257,724	337,000

Belgian Congo.*

Diamond.—Intrusive masses of kimberlite to the number of about a score occur on either flank of the Kundelungu plateau in the Katanga division. A few have proved to be diamantiferous, but none worthy of exploitation.

Alluvial diamond deposits have been located in several areas. In the Katanga district diamond has been found in the beds of the Luchipuka and Luanza rivers but no workable deposits are known there, and from the valley of the Mutendele river, a tributary of the Lualaba, small stones have been recovered, but here also no profitable deposits have been found.

The extensive and valuable deposits lie in the basin of the Kasai river farther west, and stretch over into Angola. Taken together, these fields now constitute the largest alluvial diamond field in the world, covering as they do an area of 150,000 square miles.

The original discovery was made in 1910 in the bed of the small river Kiminina near the great waterfall Mai Munene. A powerful Belgian-American company, the Société Internationale Forestière et Minière du Congo (always known as the "Forminière"), which had commenced an intensive development of the country, sent out prospecting expeditions to the district with the result that at the end of 1912, 2,540 stones had been found and a considerable area stretching south-west to north-east had been proved to contain valuable diamantiferous alluvial deposits.

* P. A. Wagner *op. cit.*, pp. 102 and 288 (See Union of South Africa). The development of the Kasai diamond fields, by H. de Rauw; (abstr.) S. Afr. Min. Eng. Journ., 1922, **33**, 1729. The diamond fields of the Kasai, Belgian Congo, by Commandant Cayen; Mining Mag., 1923, **28**, 336. The Congo-Angola diamond fields, by S. H. Ball; Mining Mag., 1925, **33**, 118 (Abstr. from Jeweler's Circular, New York).

Diamond was found in the valleys of the Tshikapa and the Longatshimo rivers and their tributaries, in those of the Lubembe and the Tshihumbo, the Luebo and the Lower Lulua, the Lubilash (Sankuru) above Lusambo, and its tributaries the Lubi and the Bushimaie.

Farther west, stones were found in the Kwilu basin up to its junction with the Kwango, in the east in the Lomami district as far as the Lomami valley, and to the south from central Angola to the Kwanza and Kubango rivers, tributaries of the Zambesi.

The diamond field is a plateau formed of a series of sandstone rocks of Jura-Triassic age lying almost horizontally, which has been deeply intersected by numerous streams running northwards. The commercial diamond deposits are all alluvial gravels occupying the valleys of these rivers but diamond also occurs, probably in commercial quantities, in some of the conglomerates in the sandstone series itself

There are two types of deposits, those in narrow valleys from 20 to 100 metres wide, averaging about 2 kilometres in length, and those in the flats deposited by larger rivers which in some cases are 500 metres across and 1 kilometre long. The deposits in the flats are usually rather thicker than those in the creeks but their average thickness is only from 1½ to 2 metres.

Production commenced just before the war and at first the washing was done by hand, but after the war mechanical plant operated by electric power was installed at the larger workings. The country has been developed by the Forminière in the most thorough manner, more than 2,500 kilometres of good roads have been constructed, farms laid out and cultivated, hospitals and dwellings constructed, electric generating stations installed, steam and motor boat services run on the river Kasai, and a narrow gauge rail service between Charlesville and Makumbi is now in operation.

Tshikapa is the centre of operations, and there are now five principal companies (all offshoots of the Forminière) working in the Congo. The Forminière company works the Tshikapa and Longatshimo rivers up to the Angola boundary, the Bécéka company works the Lubi and Bushimaie rivers and tributaries of the lower Lulua river, the Kasai company works the left-hand tributaries of the Luebo and several tributaries of the Kasai, the Luebo company works the Kabissekelele, Bisele, and Tshapembe deposits, and there is a new company known as the Lueta.

The gravels vary considerably in diamond content from a fraction of a carat to 10 carats per cubic metre, a yield of one carat being considered a very satisfactory economic proposition. The diamonds also vary considerably in quality from black bort to the finest blue-whites, and in size from " sand " to over 44 carats. The larger stones are found in the southern part of the area, in the upper part of the Kasai tributaries. On the average the stones weigh from 8 to 12 to the carat and parcels sent out usually contain 10 per cent. of stones of 1 carat and more, and 20 per cent. from ½ to 1 carat. Associated with them in the gravels are numerous pebbles of chalcedony, agate, jasper and flint, and the heavy minerals are represented by abundant black staurolite and also brown staurolite, kyanite, ilmenite, tourmaline, chrysoberyl and garnet, and a host of less abundant minerals. The occurrence of shaped flints in the gravels points to the fact that primitive man was in existence when the streams were depositing the diamantiferous gravels. The stones are not greatly water-worn, but cleavage fragments are fairly common.

The deposits in the Bushimaie valley differ considerably from the other fields, the diamond being in small quantity and associated with ilmenite, garnet and diopside, staurolite being absent, so that the concentrates here resemble those from the South African pipes, whereas the Kasai gravels closely resemble those of Somabula in Southern Rhodesia.

The original source of the Congo diamond is obscure, but the stones are older than the kimberlite pipes.

The working of the deposits is by pick and shovel and the gravel is taken to the plant by barrows, trucks or cables, pockets and cracks in the bed-rock being carefully picked out. After sizing in trommels, concentration is effected in pans of the South African type, followed by Harz jigs and finally hand-picking. The output of all the companies goes to a sales office in Antwerp.

Production has of recent years gone ahead very rapidly, and in 1931 amounted to over 3½ million carats, so that the Belgian Congo now heads the list of world producers of diamond so far as quantity is concerned. The Bécéka company, which only commenced production in 1920, contributed more than 2¾ million carats in 1931, but very little of this material is of gem quality.

The government of the Belgian Congo is largely interested in the production of diamond. It has been allotted half of the capital of the Forminière, Kasai, Luebo and Lueta companies, and the Bécéka company pays to the State, after deducting 5 per cent. dividend for shareholders and making a necessary allocation to reserve, half of the remaining profits.*

Other gemstones.—The Compagnie Minière des Grands Lacs Africains owns deposits containing *sapphire* in the valleys of the Ulindi and Elila rivers, tributaries of the Congo river, from which some stones have been produced.

---

* The Times Trade and Engineering Supplement, Dec. 18th, 1926, p. 73.

Belgian Congo.—Exports of Precious and Semi-precious Stones, crude or simply cut, but not mounted (Domestic Produce).

Year.	Quantity (carats).	Value (£).
1928	1,500,278	588,550
1929	1,895,318	752,327
1930	2,086,768	786,567
1931	3,669,316	1,054,000
1932	3,751,719	1,036,000

Egypt.*

Egypt has in the past been a producer of emerald, peridot and turquoise and probably of other stones.

The ancient *emerald* mines of Gebel Sikait and Gebel Zubara in the hillsides close to the Red Sea were probably first worked some 2,000 years before the Christian era, and no doubt supplied the bulk of the emerald used in ancient and mediaeval jewellery. Hundreds of shafts were sunk and the working extended to a depth of some 800 feet. The emerald occurs as hexagonal crystals in mica- and talc-schists, but most of the stones are of a pale greenish white colour, full of flaws and quite unsuitable for gem purposes. Three attempts to work the deposits in the last 150 years have proved unprofitable. In the vicinity of these emerald mines there are old *topaz* mines.

Zeberged, or St. John's Island, in the Red Sea, has been an important source of *peridot*, which occurs as fine flawless crystals of deep yellowish green colour in veinlets of serpentinized peridotite on the eastern side of the island. Stones of considerable size have been found and when cut have often weighed 20 or 30 carats. Formerly the deposits were worked by the ex-Khedive of Egypt and the stones were sent to France for cutting, but the workings were closed in 1914, since when there has been no production. The lease is now held by the Red Sea Mining Co. There is a royalty of 10 per cent. on the value of all rough stones extracted.

Turquoise was mined in Sinai by the ancient Egyptians, principally at Serabit el Khadem and the Wadi Moghara, and the precious stone is still collected from time to time by local tribesmen who bring it to Egypt for sale. The turquoise occurs as a filling in joints and as small concretionary nodules in two hard ferruginous seams in a purple-grey sandstone of Carboniferous age, capped by basalt. An attempt to work the deposits systematically in 1900 failed. The stones are of variable quality and production is small.

The remains of ancient workings for *amethyst* have been found in a drusy red granite near Gebel Abu Diyeiba in the Safaga district.

*** Rept. on the Mineral Industry of Egypt; Mines and Quarries Dept. Egypt, 1922. Rept. of the Mines and Quarries Dept. Egypt, 1928.**

French Equatorial Africa.*

Diamond.—An agent of the Compagnie Equatoriale de Mines sent out to prospect in the territory of Ubangi-Shari reported that in three months of 1929 he found 49 stones of good quality in the region north-east of Bria. The stones were found in the alluvium of several tributaries of the Kotto river, notably the Dji, the Boulouba and the Banguir. Three of the stones weighed more than one carat and the average was 7 to the carat.

Further prospecting in 1930 revealed the existence of workable deposits, and exploitation began early in 1931. The output in 1931 was 1,509 carats, and stones weighing up to five carats were included : in 1932 the output was 1,644 carats, but operations are said to have been suspended since September, 1932.

The formation from which the diamond is said to be derived is a conglomerate consisting of well-rounded pebbles of quartz, quartzite, chert and jasper in an arkosic matrix, and the diamond is associated in the concentrates with tourmaline, rutile, ilmenite, kyanite, staurolite, zircon, chrysoberyl and topaz, and with traces of gold and platinum. The method adopted for recovering diamond from the gravels is similar to that employed in the Belgian Congo, using hand rockers and Joplin hand jigs, the diamond being finally picked out by hand.

This is the first occasion on which workable deposits of diamond have been found on French territory.

French West Africa.†

Beds of *jasper* are worked in the Niger Province near the village of Nattangou in the valley of the Mékrou. About 50 workers are employed and the output in 1928 was 45 baskets, each containing about 100 pebbles of moderate size. The best quality fetches about 500 francs a basket at Ilorin in Nigeria.

Jasper is also said to be abundant in the valley of the Senegal river between Toukoto and Kayes and also farther north near Néma.

Madagascar.‡

In the island of Madagascar, true precious stones are very rare, but the semi-precious kinds are quite abundant. The latter are

* Echo des Mines, Aug. 1, 1930, p. 617 and July 20, 1931, p. 607. Diamonds in Equatorial Africa, by J. L. Middleton; Eng. Min. Journ., 1932, 133, 285.

† Bull. mensuel de l'agence économique de l'Afrique occidentale française, Nov. 1929, p. 342. L'Afrique Française, Rens. Colon., 1931, No. 5, 260,

‡ Minéralogie de Madagascar, by A. Lacroix; 1922, Vol. 2, pp. 80–120. Bull. des Mines de Madagascar (monthly).

obtained for the most part from pegmatite dykes or from eluvial deposits derived from them, but seldom from alluvial gravels.

Among the precious stones, *sapphire* and *ruby* have been obtained from alluvial deposits of the Ankaratra river, from Morarno, Ifempina, the Belambo river and west of Mahanoro, but the stones are small and the production insignificant. *Precious opal* occurs in altered trachyte at Faratsiho but in too small pieces to be of much value.

Among the semi-precious stones, those which are obtained in greatest quantity are *beryl*, *tourmaline*, *garnet*, and several varieties of *quartz* and *agate*. Others which have been exploited include *kunzite*, *topaz*, *spinel*, *chrysoberyl*, *cordierite*, *amazon stone* and a golden-yellow *felspar*, *zircon* and a number of others less commonly used as gemstones.

Beryl is widely distributed in the island and is notable for the great variety of colour which it displays. The most valuable colours are the deep blue and the rose-pink (true emerald being absent), but colourless, yellow, sky-blue, greenish-blue and green shades are more commonly met with. Lacroix mentions nearly 50 localities where beryl is obtained, the principal districts being those of Ankazobe, Tsaratanana, Port Bergé, Maevatanana, Betafo, Antsirabe, Ambatofinandrahana, Miandrivazo, and Fianarantsoa. Rose-pink beryl known as *morganite* comes principally from Tsilaizina, Anjanabonoina and Ampangabe. These stones are often of considerable size. In addition to precious beryl, the common variety is produced in some quantity for use in the manufacture of beryllium or its salts.

The *tourmaline* of Madagascar is also of very varied colour. The red variety (*rubellite*) is the most precious, while the colourless tourmaline is perhaps the rarest. Other colours include rose-pink, amethyst, shades of yellow, brown and green, and the deep blue variety known as *indicolite*. All the stones now obtained come from eluvial deposits derived from pegmatite at Anjanabonoina.

Two varieties of *garnet*, *spessartine* and *almandine-pyrope*, are produced in Madagascar for use as gems. The former which comes from near Tsilaizina is of yellowish-orange colour and the crystals are difficult to extract from the pegmatite, so that stones of more than 2 carats are rare. A less attractive brownish variety is found at Anjanabonoina. The almandine-pyrope, which is of deep red to violet colour, comes from many districts where gneiss and felspathic amphibolites are found. The principal localities are Fianarantsoa, Betroka, Ihosy, Fort-Dauphin and Marolambo. It is not used very much as a gem, but a considerable amount has been employed in making watch and other pivots.

Rock-crystal and several coloured varieties of quartz are obtained in the island. The former is obtained in fine clear crystals from hollows in the quartzites of the crystalline massif, especially at Menavato, Betaimboraka, Mangataboahangy, and Sahamadita. It is used to a small extent in jewellery but mainly for industrial purposes. *Rose-quartz, citrine* and *smoky-quartz* are obtained at Tsileo, Amparikaolo, and south of the Mania respectively. *Amethyst* is rather abundant in some of the pegmatites, especially at Tongafeno, Ampangabe and Ambatomanga: it is often of very superior quality. *Opaline quartz* which can be cut into rather effective ornaments occurs at Itrongay and Mahabe.

Chalcedony in many beautiful varieties occurs abundantly in the basalts and also in certain sedimentary formations in the northwestern and western coastal districts of the island. The varieties include banded *agate, onyx* and *sardonyx* as well as *plasma* and *jasper* in many different shades. The chalcedony is used, not only for making small ornaments, but also for mortars, rollers for leather dressing, burnishers, knife-edges for balances, etc.

The *kunzite* variety of *spodumene* which varies in colour from colourless to yellowish, greenish or lilac has been obtained in several localities. Only the lilac-coloured stones are saleable, and the only source at present is Anjanabonoina.

Topaz is obtained from alluvial deposits of the Saka river and from pegmatites at Mahabe and Soarano.

The principal *spinel* is a black *ferropicotite* used for mourning jewellery, which comes from Nosy Mitsio.

Chrysoberyl has been obtained from alluvial deposits of the Belambo and Ifempina rivers and from beryl pegmatites in the district of Ankazobe.

Cordierite ("water-sapphire") has been obtained from Mt. Tsilaizina, *amazon stone* (green microcline felspar) from several of the pegmatites around Anjanabonoina, Imody, Mahabe, Andina, etc., and *zircon* from the neighbourhood of Itrongay and the basaltic alluvial rocks of the Ankaratra river.

The golden-yellow *felspar* found in a pegmatite at Itrongay has also been used as an ornamental stone. It is apparently unique, being a variety of orthoclase in which ferric oxide replaces alumina.*

Among rarer stones may be mentioned clear sea-green *kornerupine* from near Betroka, deep yellow *danburite* from Mt. Bity and Maharitra, and yellow *scapolite* from Tsarasaotra.

The published statistics of output do not record the individual minerals mentioned above separately.

---

* **Chemical study of some felspars, by K. Seto; Sci. Rep. Tôhoku Imp. Univ Sendai, Japan, Ser. 3, 1923, 1, 219–231. Abstr. in Min. Abstr. 1925, 2, 403.**

Madagascar.—Production and Exports of Gemstones.

Year.	Production.		Exports.	
	Beryl, tourmaline, sapphire, etc. Quantity (kilos.)	Garnet, amethyst, etc. Quantity (kilos.)	Beryl, tourmaline, sapphire, etc. Quantity (kilos.)	Garnet, amethyst, etc. Quantity (kilos.)
1926 ...	181	3,461	156	2,238
1927 ...	252	4,869	191	5,977
1928 ...	272	3,517	138	2,563
1929 ...	273	5,664	147	6,687
1930 ...	82	4,234	36	2,575
1931 ...	43	4,600	51	1,270
1932 ...	(*a*)	(*a*)	14	451

(*a*) Information not available.

Honduras.

Precious opal occurs as irregular veins in trachyte in the department of Gracias, especially near Gracias a Dios, Intibuca and Erandique. The material is similar to " Hungarian " opal and of good quality, but the deposits are somewhat inaccessible, and little information concerning them appears to be on record.

Mexico.*

The only precious stone of importance produced in Mexico is *opal*. It is worked at present only in the State of Querétaro, the principal localities being in the districts of Tolimán, Amealco and San Juan del Río, the chief mine being the Jurado. The opal occurs as layers and cavity fillings in a porphyritic trachytic rock, and is of many varied types, but, although some very fine stones of remarkable colour are produced, Mexican opal is not so highly esteemed as that from Australia or Czechoslovakia. This is no doubt due in part to the fact that a good deal of material of poor quality is produced, and to the belief (if not the fact) that the stones have a tendency to lose their beauty in time.

Formerly opal was obtained at Zimapán in Hidalgo, but the magnificent *fire-opal* of this locality is now said to be exhausted. Small amounts of opal are obtained near Huitzuco and San Nicolás del Oro, in the State of Guerrero, and also in other States.

The opal is cut and polished locally at Querétaro in a rather crude fashion, and much of it is disposed of by selling to tourists both in Mexico and the United States.

Garnet occurs at several localities, *pyrope* near Lake Yaco, in Chihuahua, and near Sonora, and *almandine* at Triunfo, in Lower California.

* Gems and precious stones of Mexico, by G. F. Kunz; Trans. Amer. Inst. Min. Eng., 1902, 32, 55–93.

Topaz occurs at many localities, but is not used as a gem.

Amethyst is common in the silver mines of Guanajuato and has a world-wide reputation, while *rock-crystal* and other varieties of quartz are also found in the country in some abundance.

Jade and *obsidian* were extensively used by the Aztecs in ancient times for the production of carved ornaments, but the localities from which the former was obtained are unknown.

Mexican onyx, or " tecali," is a most beautiful ornamental stone which is highly esteemed, being easily carved into ornaments and trinkets. It is a variety of *calcite* containing coloured bands due to iron staining, and is found in numerous limestone caves in the form of stalagmites. It is most commonly worked in the States of Puebla and Oaxaca, especially at Tecali, Tehuacán, Etla, Tlaxiaco and Juxtlahuaca, and has also been obtained from a locality east of San Fernando, in Lower California.

United States.*

While it is probable that the United States has produced precious stones in greater variety than any other country, the industry has never been important, and the output and value have always been comparatively insignificant.

Diamond has been found as isolated crystals in many of the States, generally in secondary deposits or glacial drift, but a more important discovery of diamond in decomposed peridotite was made near Murfreesboro, Pike County, Arkansas, in 1906. Several mining companies commenced operations and several thousand stones have been produced, but the quantity is not accurately known. The stones vary greatly in size, but the average of the entire production was estimated in 1923 to have been only between 0·3 and 0·4 carat.

The largest diamond yet found in North America was a flattened octahedron of 40·22 carats, obtained from these deposits in 1924. There is a large proportion of white stones of excellent quality together with brown and yellow ones and very little bort. No information has been published as to the output in recent years, but only two men were working the deposits in 1924.

Sapphire† has been the most important gemstone obtained in the United States. The principal deposit is at Yogo Gulch near Utica, Montana, where sapphire was mined by an English company from a much-weathered monzonite dyke which is almost vertical and

* Mineral Resources of the United States, Gems and Precious Stones; U.S. Geol. Survey (discontinued 1921). Gems and Gem Materials, by E. H. Kraus and E. F. Holden; 2nd edit., New York, 1931. The Mineral Industry (Annual).

† The sapphire mines of Yogo, Montana, by O. W. Freeman; Min. Sci. Press, 1915, 110, 800–802. Minor metals and non-metallic minerals of Montana, by J. P. Rowe; Eng. Min. Journ., 1928, 125, 817.

from 8 to 20 feet thick. The better stones were sold in London, and others in Paris and New York, but the bulk of the output was suitable only for industrial purposes, and this was mainly consumed in Switzerland. Operations were suspended in 1929. The output from the Yogo deposit for the years 1924-27 was as follows* :—

	1924. (carats).	1925. (carats).	1926. (carats).	1927. (carats).
Gem sapphire	46,950	54,495	42,469	6,451
Industrial stones	278,317	211,873	179,895	83,235

Sapphire and ruby have also been won from the gravels of Rock Creek in Granite County, Cottonwood Creek in Powell County and along the Missouri River near Helena, all in Montana, but very little is of gem quality. Sapphire, especially the green variety, has also been obtained at Corundum Hill and Cowee Creek in Macon County, North Carolina.

Of the many other gemstones found in the United States, the most important from the point of view of production appear to have been turquoise, tourmaline and opal.

Turquoise has been produced principally in Nevada from near Crescent in Clark County, near Crow Springs and in the Monte Cristo mountains, Esmeralda County, where it occurs as nodules embedded in a clay-like matrix filling fractures in a decomposed granite-porphyry. Similar deposits have been worked for turquoise across the border near Silver Lake in San Bernardino County, California, and abundant evidence exists that these were worked by the aborigines on a considerable scale. In Arizona, turquoise occurs as veinlets in quartzite and in decomposed granite at Turquoise Mountain in Cochise County, and has been worked there. It has also been worked near Las Cruces in the Jarilla mining district of New Mexico, near Van Horn in Culberson County, Texas, near Manassa in Conejos County, Colorado, and elsewhere.

Tourmaline of gem quality has been produced in numerous localities, the chief of which are in San Diego County, California, and in Oxford and Androscoggin Counties, Maine. The best of the Californian tourmaline has come from pegmatite dykes in the vicinity of Mesa Grande, where it is associated with kunzite and other lithium minerals. Pink, red, yellow, green and blue stones of excellent quality have been produced. Many of the red stones, which are often of considerable size, are exported to China, where they are carved and re-exported. Among other localities may be mentioned Chesterfield and Goshen, Massachusetts; Haddam, Connecticut; Gouverneur, De Kalb and Pierrepont, New York; and Chester County, Pennsylvania.

Precious opal has been produced mainly from Virgin Valley in Nevada, and in Latah County, Idaho. In the former locality, some

---

* Mineral Industry, 1929, p. 550.

very fine black opals have been found in association with petrified wood in ashes and tuffs of Miocene age.

Semi-precious varieties of *quartz* are produced in many States, usually in conjunction with felspar mining.

Agate of various types is fairly common in California, especially in the Death Valley region, and moss-agate is obtained along the Yellowstone River in Montana, and from the Sweetwater Valley in Wyoming.

Beryl occurs at many localities in the New England States of which the most important are near Stoneham, Albany, North Lovell and Buckfield, Maine; Beryl Hill near Royalston, Massachusetts; Melvin Hill near Grafton and Beryl Hill near Acworth, New Hampshire. That from the Buckfield locality is often very pale in colour and contains caesium replacing beryllium. Beryl crystals of prodigious size have been met with in the Bumpus felspar quarry, Albany, Maine, and in the Ruggles mine near Grafton, New Hampshire, but these are not of gem quality. Rose-pink beryl is found in San Diego County, Colorado, and an occasional *emerald* is met with in the crystalline rocks of North Carolina. Beryl also occurs in the Black Hills, South Dakota.

Felspar of the variety *amazon stone* is especially abundant in the Pikes Peak region of Colorado, and *sunstone* has been obtained from Modoc County, California.

Lapis lazuli (*lazurite*) has been obtained in California and *lazulite* in Arizona.

Rhodonite from some of the old silver mines of Butte, Montana, and from various localities in California has frequently been employed in jewellery, and numerous copper-ore minerals, mainly from Arizona, have been used in a similar way.

Topaz has been worked intermittently in Montana, Maine, Colorado, Utah, New Hampshire, California, Texas and occasionally elsewhere.

Among the more unusual gem minerals occurring in the United States may be mentioned the *kunzite* variety of spodumene, found in pegmatites near Pala, California and called " California iris," and the *hiddenite* variety, which occurs at Stony Point, Alexander County, North Carolina. *Variscite*, a phosphate of aluminium, rather like turquoise in appearance, has been produced in Utah, notably at Lucin and in Tooele County. *Thomsonite* and *chlorastrolite* are picked up as beach pebbles at Isle Royal, Lake Superior, having been weathered out of the basic igneous rock in the vicinity.

Some idea of the immense variety of minerals classed as precious stones in the United States may be gained from the last table of production published by the U.S. Geological Survey (1921), in which 42 different minerals are mentioned. The total value of the production in that year, however, was only about $500,000, and more than 90 per cent. of this was accounted for by Montana sapphire.

The United States is the principal buyer of the world's precious stones, especially of diamond, and it is very largely because of the smaller demand for these stones, consequent upon the economic depression in that country, that the diamond market has latterly been in such a depressed condition.

United States.—Total Imports of Precious Stones.

Diamond.

Year.	Rough.		Cut.		Industrial.	
	Quantity (carats)	Value (£)	Quantity (carats)	Value (£)	Quantity (carats)	Value (£)
1928 ...	291,302	2,451,765	440,437	8,709,154	38,342	566,330
1929 ...	354,367	2,033,761	416,992	8,649,286	46,949	837,487
1930 ...	209,591	1,160,179	295,391	8,640,391	145,958	566,974
1931 ...	85,249	830,400	201,998	2,656,400	224,970	513,400
1932 ...	40,153	431,500	183,103	2,232,200	163,704	302,900

Other Precious Stones.

Value (£).

Year.	Rough.	Cut.
1928	60,092	1,194,867
1929	72,484	1,854,598
1930	37,354	1,006,959
1931	79,200	319,700
1932	15,300	208,300

The above figures show not only that the importation of high-priced diamonds has greatly decreased, but also that there has been a great increase in quantity and decrease in value of stones for industrial purposes, due no doubt to the substitution of bort for carbonado. In June 1930 the United States import duty on cut stones was reduced from 20 to 10 per cent., while rough stones were admitted free of duty.

Argentina.*

A number of semi-precious stones are stated to have been obtained in various parts of the country, but they appear to be only of local interest.

Pyrope garnet occurs in alluvial deposits near San Martín and Quines in San Luis and in the bed of the Río Mina Clavero in Córdoba, while *agate* and various other forms of *chalcedony* are

* Breve recopilación de los yacimientos de materias explotables de la República Argentina, by R. Beder; Direcc. Gen. de Minas, Geol. e Hidrol., Buenos Aires, Bull. 26, Ser. B, 1921, pp. 24–25.

met with in the provinces of Corrientes and Entre Ríos and as veins in manganese ore in the Aguada del Monte (Córdoba) and at Los Ancoches (Santiago del Estero).

Beryl occurs at many localities especially in pegmatites at Riocito and elsewhere in the mountains of San Luis. *Rose-quartz* has been found in the same locality and in Córdoba.

Brazil.*

Diamond.—The discovery of diamond near Diamantina (formerly Tejuco), in the State of Minas Geraes, about the year 1725, resulted in Brazil becoming the world's chief source of this precious stone, a position which was held for a century and a half. Later, discoveries were made in other parts of the same State and also in the States of Bahia, Goyaz, Matto Grosso, São Paulo, Paraná, Piauhy, Maranhão and Amazonas, but the most important producing areas are in Bahia, Minas Geraes and Matto Grosso. Since the discovery of the much more valuable deposits in South Africa the importance of Brazil as a producer of precious diamond has greatly declined.

The deposits in Minas Geraes† are of two classes, plateau or high-level deposits, and river or valley deposits derived from the former. The high-level deposits occur for the most part high up on the ridges forming the divides between the river valleys, especially in the Serra do Espinhaço, a mountain range extending about 600 miles northwards from Ouro Preto to Joazeiro, and its western offshoot the Serra do Cabral.

Moraes and Guimarães divide the formations in this area into three series; (1) a series of metamorphosed phyllites, quartzites, itabirites and limestones, chiefly occurring in the south of the area, known as the Minas Series, believed to be of pre-Cambrian age and not known to be diamantiferous; (2) a series of quartzites, sandstones, conglomerates and phyllites including itacolumites, known as the Itacolomy Series, all much folded and faulted, which overlie the Minas Series unconformably, and are also believed to be of pre-Cambrian age. They occupy the greater part of the area and are diamantiferous; and (3) a series of conglomerates, phyllites and sandstones resting unconformably upon the above series

---

* Mineral deposits of South America, by B. L. Miller and J. T. Singewald, 1919 pp. 207–215 (bibliography, pp. 218–232). Mineral resources of Brazil, by E. P. de Oliveira; Serv. Geol. e Mineral. do Brasil, 1930, pp. 6 and 7. Ann. do Minist. da Agric., Indust., e Comm., Brasil, 1930, pp. 199–209.

† The high level diamond-bearing breccias of Diamantina, Brazil, by D. Draper; Trans. Geol. Soc. S. Afr., 1920, 23, 43–51. O diamante no Estado de Minas Geraes, by D. Guimarães, and Algumas jazidas de diamante no norte de Minas Geraes, by L. J. de Moraes; Bol. 24, Serv. Geol. e Mineral. do Brasil, 1927. The diamond-bearing region of northern Minas Geraes, Brazil, by L. J. Moraes and D. Guimarães; Econ. Geol., 1931, 26, 502–530.

and believed to be partly metamorphosed fluvio-glacial deposits of early Cambrian or late pre-Cambrian age. These also are diamantiferous and are known as the Lavras Series.

The Itacolomy Series is traversed by pegmatite and diabase dykes and by intrusions of a very much altered rock in which diamond occurs, known as diamond matrix.

The most important diamond mines are at São João da Chapada, Perpetua, Pagão, Campo de Sampaio, Boa Vista, Serrinha, Sopa, Guinda and Dattas, near Diamantina; at Grão Mogol in the Minas Novas district, about 150 miles to the north; at Burity Grande, Barreiro and Jequitahy, on the N.E. slopes of the Serra do Cabral; and at Agua Suja near Bagagem, on the border of Goyaz State.

The mode of occurrence of diamond in these deposits varies considerably, and the many geologists who have examined and described them have placed widely different interpretations upon their observations.

According to the views of Moraes and Guimarães, who have studied the problems closely in recent years, the deposits at São João da Chapada, Perpetua, Pagão, and Campo de Sampaio belong to the Itacolomy Series in which the diamond occurs in a rock known as diamond matrix.

This material is described as an "eruptive breccia" known locally as *barro* or *massa*, the boulders of which are usually angular blocks of decomposed quartzite and shale or phyllite, similar to the country rocks, embedded in a soft clay-like matrix.

This soft matrix, which contains the diamond, is soapy to the touch, may be white, pink or grey in colour, and exhibits flow-structure. It appears to be made up of sericitic and kaolinitic material, and evidently represents a rock which has been completely altered since its injection. An average of four chemical analyses of this material showed that the main constituents were 45·39 per cent. of silica, 27·6 per cent. of alumina, 10·37 per cent. of alkalis, and 5·75 per cent. of combined water.

Accessory minerals are most commonly quartz, haematite and magnetite, while monazite, tourmaline, kyanite, xenotime, zircon and rutile are also present.

The iron oxides which form bands, are probably not original constituents, and except for these oxides, the Brazilian geologists point out that there is nothing suggestive of an original basic nature for the diamond matrix.

D. Guimarães has suggested that it was originally a granitic rock.

D. Draper,* who believed the soft matrix to consist largely of talc, was also of the opinion that the rock was intrusive or eruptive but considered that it arose from the decomposition of kimberlite or some allied rock.

---

* Trans. Geol. Soc. S. Afr., 1920, 23, 50–51.

E. C. Harder and R. T. Chamberlin* considered the diamantiferous rock to have been deposited by streams, but were undecided as to whether the diamond originally came from the underlying quartzite or from igneous rocks outside the area. In the case of São João da Chapada they conceded that the original drainage channel of the supposed stream may have been determined by a pegmatitic dyke.

O. A. Derby,† who described this deposit in great detail, considered that the most suitable hypothesis for its origin was that of a pegmatitic vein with contact metamorphism, and he confirmed by careful chemical analysis the sericitic nature of the cement.‡

On the other hand, L. S. Thompson§ concluded that the breccia resulted from a basic intrusion.

The balance of modern opinion favours an intrusive origin for the diamond breccia, and chemical analysis of the matrix, supported by the character of its mineral contents, suggests that although the diamond-bearing rocks were deficient in quartz they were not ultrabasic.||

The deposits at Boa Vista, Serrinha, Sopa, Guinda, Dattas, and Grão Mogol, on the other hand, are said to be ancient diamantiferous conglomerates of the overlying Lavras Series. At Boa Vista the conglomerate is some 20 metres thick and the large pebbles of quartzite, phyllite, quartz and sandstone, which it contains, are in part rounded and in part subangular, many appearing to have been transported by glacial agency.

The deposits on the north-east slopes of the Serra do Cabral also appear to belong to the Lavras Series, but that at Agua Suja seems to be in a class by itself, as the diamond breccia here seems to be made up of rocks of an ultrabasic type, and the deposit is therefore said to have some analogies with the kimberlite pipes of South Africa.¶

At the Boa Vista mine (which is about 4,000 feet above sea level) the workings are over a mile in length, about 100 yards in width and over 70 feet in depth in places. At the São João de Chapada (about 5,000 feet above sea level), the breccia covers an area of about one square mile, and the bottom was not reached in a borehole 130 feet deep. The Serrinha deposit covers an area of about half a square mile, and the diamantiferous breccia has been excavated in a series of cuttings and pits to a depth of 40 feet. It is sufficiently soft to be readily broken down by jets of water.

---

* Journ. Geol., 1915, 23, 415–421.
† Journ. Geol., 1898, 6, 139.
‡ Amer. Journ. Science, 1900, 10, 207–216.
§ Econ. Geol., 1928, 23, 713–716.
|| Über die Diamantlagerstätten des Hochlandes von Diamantina, Minas Geraes, Brasilien, by C. W. Correns; Zeits. f. prakt. Geol., 1932, 40, 161–168 and 177–181.
¶ The diamond-bearing deposits of Bagagem and Agua Suja in the state of Minas Geraes, Brazil, by D. Draper; Trans. Geol. Soc. S. Afr., 1911, 14, 8–19.

Although there has been a large production from the mines enumerated above, by far the greatest output has come from detrital deposits formed *in situ* known as *grupiáras*, and from the alluvium or *cascalho* in river valleys.

In Minas Geraes these are chiefly in the valleys of the Jequitinhonha river and its western tributaries, others which have been worked being the Abaeté, Somno, Bagagem, Sapucahymirim, upper Rio Grande, São Antonio, Prata, and São Francisco rivers.

In Goyaz, diamond has been won from the valleys of the upper Araguaya,* Paranahyba, Verissimo, Pão Secco, Capivari and other rivers, while the Garças, Coxim, Jaurú and Cuyabá rivers in Matto Grosso, the Paraná, Paranapanema and Verde rivers in São Paulo, and the Tibagy, Japão, Cinzas, and Pitanguy rivers in Paraná have also contributed in more or less degree to the output. Stones have also been reported from Borracho Fonda in Piauhy, from the Secco river in Maranhão, and from the Branco basin in Amazonas.

The diamond deposits of the State of Bahia† call for special mention because in them the bulk of the stones are of the variety called *carbonado*, which is used for industrial purposes, but the precious variety occurs with them, roughly it is said, in the proportion of 3 carbonados to 1 diamond. Precious diamond is also found in Bahia, unaccompanied by carbonado, near Salobro in the Canavieiras area in the south-eastern part of the State, but climatic conditions here are stated to be very trying and the gravels are no longer worked.

Carbonado often occurs as pieces of considerable size and the largest recorded, which was found in 1895, weighed 3,078 carats. The stones are all obtained from alluvial deposits in the district known as the Chapada Diamantina in the southern part of the State, east of the São Francisco river, chiefly from the gravels of the Paraguassú river and its tributaries around Lençóes and Morro do Chapéo. The diamond is only found in and about the beds of streams which have cut their courses through a series of pinkish sandstones and conglomerates belonging to the Lavras Series, and diamond is said to have actually been found *in situ* in these rocks.

It has generally been assumed therefore that both diamond and carbonado have been derived from the Lavras beds.

Carbonado is also found in the beds of streams in the north of Minas Geraes, especially in the Macahubas river, but none of these industrial stones has been found south of Grão Mogol. The winning of carbonado, like precious diamond, is carried out very

---

*** Diamond deposits on the Upper Araguaya River, Brazil, by F. W. Freise; Econ. Geol., 1930, 25, 201–207.**

† The geology of the diamond and carbonado washings of Bahia, Brazil, by O. A. Derby; Econ. Geol., 1905–6, 1, 134–142. The diamond-bearing highlands of Bahia, by J. C. Branner; Part 1, Eng. Min. Journ., 1909, 87, 981–986. Notes on the geology of the diamond region of Bahia, Brazil, by R. Crandall; Econ. Geol., 1919, 14, 220–244.

largely by hand methods, and the skill required in picking out these stones from the concentrates is very considerable.

There has been a severe fall in the price of rough carbonado ("carbons") in recent years; in 1928 best grade stones fetched about £40 per carat, in 1932 they had fallen to about £10 and in March, 1933, the ruling prices were about £3 to £5 in Brazil.

Throughout Brazil the winning of diamond is still most commonly carried on by the primitive native method. At several places, where the rivers are sufficiently wide, dredges have been employed with some success, especially on the Jequitinhonha near Diamantina, and modern diving equipment has been used on the Araguaya river in Matto Grosso.

The common native method of recovering diamond is to dig the earth with a hoe, and carry it in a wooden vessel to the stream, where it is deposited a little at a time into a sloping three-sided box, open to the stream. Here water is thrown upon it from a *batea*, thus washing away the clay and lighter particles into the stream. The residue is afterwards concentrated in the batea and the diamond is hand-picked from the concentrate. The method is stated to be efficient.

It is also a common practice, especially in Goyaz, for natives to dive into the streams carrying a heavy weight and a bag or basket. The weight keeps them below while they fill the receptacles with diamantiferous gravel from the river bed.

As has been said, practically the entire output of diamond in Brazil comes from alluvial workings at the present time. None of the deposits appear to be either extensive or exceptionally rich and almost all are in the hands of small operators.

As the occurrences are so widespread it is not surprising that the characters of the stones produced vary considerably, and many diverse types are found. A large proportion of the stones are, however, of excellent quality.

Among famous Brazilian stones may be mentioned the *Dresden* and the *Estrella do Sul*, both of which came from the Bagagem river near the town of that name in Minas Geraes. The former (not to be confused with the *Dresden Green*) weighed 119½ carats uncut, and 76½ carats after cutting into an egg-shaped brilliant; the latter weighed 254½ carats when found and was cut in Amsterdam into a fine brilliant of 128·5 metric carats.

The Abaeté river is said to have yielded a stone of 161½ carats, and the Verissimo river in Goyaz is said to have produced a stone of 600 carats which was destroyed.

O. A. Derby has described a stone called the *Estrella de Minas* which weighed 225 carats in the rough, while a stone of the first water is stated to have come from the Serrinha deposit in 1914 which weighed about 310 carats. Early in 1931 it was reported that a stone of 574 carats, the largest ever found in Brazil, had been obtained in Matto Grosso.

In addition to diamond, Brazil is an important source of a number of other gemstones.* These include *emerald, beryl, chrysoberyl, topaz, tourmaline, garnet, agate, amethyst* and *rock crystal.* The principal markets for semi-precious stones are at Theophilo Ottoni, in Minas Geraes, and at Conquista, in Bahia.

Emerald was found in 1913 in the interior of Bahia near Bom Jesus dos Meiras.† The stones occur in an altered marble capping a mountain. Emerald crystals are found along with quartz and calcite in drusy cavities which occur in the vicinity of talc veins occupying vertical joints in the marble.

The crystals are well-developed hexagonal prisms and are often doubly terminated, but few of the stones are of sufficiently deep colour to rank as high-grade gems, and a large majority are rendered semi-opaque by fractures and flaws.

Mining is carried out intermittently by primitive methods in a crude open cut, and up to the end of 1925 about 20 kilograms are said to have been produced. The emerald referred to above is the true emerald as distinct from " Brazilian emerald " which is a synonym for green Brazilian tourmaline.

Beryl of gem quality is very abundant in Brazil.‡ The chief localities in Minas Geraes are on the lower Jequitinhonha from São Miguel to Minas Novas, and on the slopes of the Serra do Chifre, north of Theophilo Ottoni, especially at Marambaia on the river Mucury, where in 1910 a crystal of gem quality weighing 112 kilograms was obtained. The stones are said to come from pegmatite veins in this region and the last mentioned locality yields deep blue stones of high value.

Other localities include the district around S. Anna dos Ferros, about 70 miles N.E. of Bello Horizonte, and S. Anna da Onça and Lajão near Figueira on the Rio Doce, in Minas Geraes; the environs of the city of Rio de Janeiro, especially in a pegmatite dyke at Glycerio, some 90 miles N.E. of the city; and various localities around Conquista in southern Bahia. Some of the beryl is of the golden variety.

Chrysoberyl of very fine quality is mainly obtained in the Minas Novas district, especially in the gravels of the Gravatá, Neves, Novo, Calhão and other streams where it is associated with amethyst, tourmaline, euclase, blue and white topaz and garnet, usually in the form of pebbles. Perfectly transparent stones are rare, most of them displaying chatoyance. The colour is very variable, yellowish-green stones predominating, and these stones are

---

* Brazil; a centenary of independence, 1822–1922, by J. C. Oakenfull; Freiburg, 1922.

† Emeralds at Bom Jesus dos Meiras, Bahia, Brazil, by E. Just; Econ. Geol., 1926, 21, 808–810.

‡ Beryllium minerals in Brazil, by L. J. Moraes; Econ. Geol., 1933, 28, 289–292.

often known in the trade as "chrysolite." Other localities for chrysoberyl are Itabira do Campo, in Minas Geraes, the river Canóas (Rio Grande) in São Paulo, and above Collatina on the Rio Doce in Espirito Santo.

Brazil has always been an important source of *topaz*, and many fine stones have been obtained. The principal locality for yellow topaz is a chain of hills extending for a distance of some six miles in a south-westerly direction from Ouro Preto, in southern Minas Geraes, where the stone occurs as nodules in a clayey matrix which is said to have resulted from the decomposition of a mica-schist.

In this locality topaz is abundant and varies in colour from pale to dark yellow, but red crystals are sometimes found which have been called " Brazilian ruby ". The deep wine-yellow stones are most highly esteemed.

Blue and colourless topaz occurs abundantly as water-worn pebbles in river gravels derived from granitic rocks in the north-east of Minas near Arassuahy, in association with beryl and chrysoberyl. Most of the blue stones are pale but the darker shades are the more valuable.

Pink topaz rarely occurs naturally but a pink colour is sometimes produced artificially by heating some of the brownish-yellow stones. Pale yellow topaz usually becomes colourless on heating, and may even do so gradually on exposure to sunlight.

The *tourmaline* of Brazil is chiefly of the green variety, but *rubellite* (red) and *indicolite* (blue) are also obtained. The principal deposits lie in north-east Minas Geraes, especially the basins of the lower Arassuahy, the Jequitinhonha and the upper Rio Doce, the mineral occurring in decomposed quartz veins in pegmatites and gneiss, and as pebbles in gravel.

The emerald-green variety was formerly thought to be emerald and is still commonly referred to as " Brazilian emerald ". Some very large and beautiful stones have been produced and the headquarters of the trade are in the districts of Porteiras, Larangeiras and Salinas where it is largely in the hands of German agents.

The blue variety, indicolite, is much less common than other types and is more highly valued. Parti-coloured stones are comparatively common.

Garnet is widely distributed in the gneissic rocks of eastern Brazil and in detrital deposits derived from them. *Almandine* occurs at Sumaré and elsewhere in Rio de Janeiro, and in the monazite sands along the Brazilian coast. It occurs also in the gravels of Minas Novas and at Agua Suja; with *pyrope* and *grossular* at Gravatá, in the Andarahy, Piabas, and São Antonio rivers, Bahia, and at Cantagallo and Santa Rita in Rio; and with *pyrope* in the Mucujé and Utinga rivers. *Spessartine* occurs in limestone rocks at Arassuahy and Registro, and in gravels in the Santa

Maria and Abaeté rivers. *Andradite* is found in the Mucujé river while *hessonite* occurs at many localities in Minas Geraes.

Agate occurs abundantly in the amygdaloidal rocks that make up the Serra Geral range, which extends westwards from Porto Alegre in Rio Grande do Sul, continuing across into Uruguay. The rocks are much decomposed so that the amygdales have weathered out and are found lying loose on the ground and also in the alluvial deposits of the rivers which rise in the range.

The agate is of many varieties including *carnelian, jasper, sardonyx, onyx,* etc., and is also accompanied by *amethyst.* The valley of the Rio Pardo and Taquairy are the principal localities for carnelian, striped agate being more common on the heights above. From the Campo de Maia, lumps of sardonyx weighing as much as 1 cwt. and of magnificent colour have been obtained.

It is from this district in Brazil and Uruguay that the greater part of the agate is obtained for the cutters and polishers of Oberstein and Idar in Germany, which are the centres of this industry. Other occurrences are at Areia and near the Paulo Affonso falls on the São Francisco river in Bahia, and along the Gurayras river in Ceará where the agate is accompanied by hyaline quartz.

Amethyst occurs in most of the Brazilian States but principally in Rio Grande do Sul, where, in the Serra do Mar, a great druse was discovered which yielded 15 tons of material of excellent quality. Other important localities are Itaberava near Ouro Preto; Bom Jesus dos Meiras; in north-east Minas Geraes, and near Coimbra in Matto Grosso.

Rock-crystal and other varieties of quartz are also obtained from Brazil in considerable amounts, the chief localities being the Serra dos Crystaes in south-eastern Goyaz, and Congonhas do Campo. *Rose quartz* is obtained in the valley of the Jequitinhonha. *Citrine,* the yellow variety of quartz, is found at many localities and is often confused with topaz.

It has recently been reported that the Nazareth railway extension will probably enable large deposits of *rock-crystal* in the interior of Bahia to be exploited. A new deposit in the Conquista district is about to be opened up.*

Exports of rock-crystal from Brazil were recorded as 308,965 kilos in 1928, 498,496 kilos in 1929, 410,591 kilos in 1930, 537,788 kilos in 1931, and 308,524 kilos in 1932. Usually the exports go mainly to Japan and Germany.

It is of interest to record that there are occurrences in Brazil of some of the lesser known semi-precious stones of which some

* **Foreign Trade Notes, U.S. Dept. Comm., No. 309, Oct. 11, 1930.**

very beautiful specimens have been obtained from time to time. These include *andalusite*, both clear green and salmon-pink, from Minas Novas, *euclase* in many shades of blue and green from near Ouro Preto, *nephrite* from the Amazon valley, and *phenakite*, sometimes of pale red tint, from near Santa Barbara, in Minas Geraes. Clear yellow *scapolite* of gem quality has recently been found on the border of Espirito Santo and Minas Geraes.

In the tables showing the world production of diamond on pp. 30-31 no figures are given for Brazil on account of the unreliability of published statistics of production and exports. It seems probable that many stones leave the country without being recorded officially.

The following estimates of Brazilian production in recent years have been obtained from dealers and others in Brazil who are in close touch with the trade.

Brazil.—Estimated production of Diamond.

	Quantity (carats).		
	Gem quality.	Low grade and bort.	Carbonado.
1928	65,000	100,000	25,000
1929	50,000	75,000	19,000
1930	45,000	70,000	17,500
1931	30,000	50,000	10,000
1932	15,000	19,000	3,000

Estimated production of Diamond by districts.

	Quantity (carats).		
	1928.	1931.	1932.
Bahia	48,000	24,000	10,000
Paraná	9,600	3,000	2,000
Diamantina	38,400	16,000	6,000
Bagagem	9,600	3,000	1,000
Goyaz and Matto Grosso ...	86,400	50,000	18,000

Official export values give no true indication of the trade as they do not include low-grade material and are based on miners' own declarations.

Chile.*

There are stated to be large deposits of *lapis lazuli* in the Cordillera of Ovalle in Coquimbo, close to the Argentine boundary, and less important deposits in Antofagasta, but there has been no production for many years.

* Stone Trades Journ., 1924, 42, 310.

Colombia.*

Sapphire and *ruby* are found in the Rio Mayo, a tributary of the Patía, and in the sands of the Platayaco, in the Caquetá territory, while *garnet*, *carnelian*, *agate*, etc., occur in various parts of the country, but none of these is of commercial importance. The *emerald* mines of Colombia are, however, world-famous, and were worked by the natives prior to the Spanish occupation in the 16th century.

About 150 occurrences have been reported, but the three commercially important localities are Muzo and Cosquez (or Coscuez), about 90 miles N.N.W. of Bogotá, and Somondoco (or Chivor), about 35 miles east of the same town. Of these Muzo has been the most important source of the stones, for, although the other deposits were worked in the early days of the Spanish occupation, both of them had to be abandoned on account of hostilities with the natives, and their locations were lost for a long period of time.

At Muzo, the deposits are situated in the midst of tropical jungle at an altitude of 3,000-4,000 ft. above sea level, on the precipitous slopes of a valley and about 200 to 500 ft. from the floor. Transport to the mines is difficult. The emerald occurs mainly in calcite veins traversing a much-folded series of black carbonaceous shales and shaly limestones of the Villeta Series, which are considered to be of Lower Cretaceous age. The emerald is associated with an interesting assortment of gangue minerals which include calcite, dolomite, parisite, pyrites, quartz and sometimes barytes, fluorspar and apatite. The stones occur as hexagonal prisms of a rich green colour and are unsurpassed by emerald from any other locality. Some of them exhibit zones of colour, and a few are darkened by carbonaceous inclusions.

All the workings are open cuts. After clearing vegetation and overburden, the emerald formation is worked in terraces or benches about 30 inches deep, the soft limestone being broken away by gangs of peons armed with long iron crowbars. The emerald-bearing calcite veins are carefully removed by hand and taken to a sorting shed, the débris being washed down into the valley below by water obtained from reservoirs specially constructed for the purpose.

---

* **Emeralds: their mode of occurrence and methods of mining and extraction in Colombia, by C. Olden; Trans. Inst. Min. Met. 1912, 21, 193–209. The emerald deposits of Muzo, Colombia, by J. E. Pogue; Trans. Amer. Inst. Min. Met. Eng. 1917, 55, 910–934. Colombia: Comm. and Ind. Handbook, by P. L. Bell; Bur. For. Dom. Comm., Special Agents Ser. No. 206, Washington, 1921, pp. 250–251. The Chivor–Somondoco emerald mines of Colombia, by P. W. Rainier, with appendices by C. Mentzel and C. K. MacFadden; Amer. Inst. Min. Met. Eng., Tech. Pub. No. 258, 1929. Republic of Colombia, Comm. Rev. and Handbook (July, 1929), Dept. Overseas Trade, 1930, pp. 57–58. Mineral Industry (Annual).**

At the sorting shed the calcite veins are broken up by hand, emerald being picked out. Finer material is washed on sloping tables, and the emerald picked out by boys. The stones are sorted into about 15 grades according to colour, size, transparency and freedom from flaws, and are then taken by mule to Bogotá.

The deposits in the Chivor district are also situated in extremely rugged country clothed in dense forests and difficult of access. Emerald occurs here under similar conditions to those obtaining at Muzo, except that the enclosing rocks seem to be less heavily impregnated with carbonaceous material at Chivor, and the emerald occurs in veins with albite, pyrites and quartz instead of in calcite veins. The veins vary from a few feet up to 200 ft. in length, and in width up to 8 inches. Emerald is found as a rule in shoots or in nests in the veins; generally the stronger the vein the richer it is in emerald. The mode of working is similar to that employed at Muzo.

The mines were rediscovered about the beginning of the present century and were operated intermittently by various interests until 1925 when they came under the control of an American syndicate. It is evident that there is a large amount of emerald-bearing ground available in the area, but production must inevitably be irregular in view of the pockety nature of the deposits.

Of recent years the grade of stones produced has become progressively higher. The colour of the stones at Chivor is usually consistent throughout a vein and often in parallel veins, but varies considerably in different zones in the deposit. The size of stones varies from minute crystals up to those weighing several hundred carats. All stones have to be accounted for to the Government and none may be transported except under official seal.

Little has been published concerning the Cosquez mines; they are very inaccessible, but were known and worked prior to the Conquest, and have a reputation for richness.

The history of the exploitation of the emerald mines of Colombia is full of interest, but here it must suffice to state that the present Muzo deposits were worked on a considerable scale by the Spaniards from 1594 to 1609. Production then dwindled, and was continued in an inefficient manner until 1824 when the mines were leased by the Republican Government.

In 1848 it was decreed that the emerald deposits were a Government monopoly, but the authorities continued to grant concessions to firms and individuals to work them and at times entered into a kind of partnership. Various arrangements were made until 1909 when the Government made a partnership agreement with an English company controlled by S. African diamond interests, and active exploitation recommenced. This was rescinded after a few years, and the Government resumed sole control. At the end of 1912 operations ceased and the mines were not reopened until 1923. They were again closed down in 1930.

Owing to prolonged litigation, a stock of emerald accumulated in the country, the whole of which was ultimately disposed of in 1923 to a French firm, with whom an agreement was also made in respect of marketing the output of the Muzo and Cosquez mines. This agreement was terminated in 1927, and further litigation ensued which has resulted in the discontinuance of active exploitation.

No official statistics of Colombian emerald production are published.

The Muzo and Cosquez mines are reputed to have produced as much as 800,000 carats of all grades in one year, and the following table gives the production of emerald at the Chivor mines in recent years (according to Rainier), but account is taken only of stones of the better grades.

Colombia.—Production of Emerald at Chivor.

Quantity (carats).

Year.	Colour 1	Colour 2	Colour 3	Colour 4	Colour 5	Total
1926 ...	—	3,170	400	11,500	28,400	43,470
1927 ...	—	4,592	11,936	15,554	5,443	37,525
1928 ...	—	505	10,668	4,299	7,240	22,712
1929 (first half).	200	4,985	10,135	—	120	15,440

The best quality stones find their way to the American, French and English markets, while the inferior grades are sent to India to be carved or cut into beads, drops, etc.

Uruguay.*

It has been stated above that the deposits of *amethyst* and *agate* of southern Brazil extend across the river into Uruguay. The principal localities are in the north-west of the country in the departments of Tacuarembo, Paysandu, Salto and Artigas, and the mode of occurrence is exactly the same as in Brazil. The stones are collected and taken to the nearest railway station where they are packed in barrels and dispatched to Salto and thence by river to Montevideo for shipment to Germany. The finest amethyst comes from Artigas.

* Gems and precious stones in 1918, by W. T. Schaller; U.S. Geol. Surv., Min. Res. U.S., 1918, Pt. 2, p. 10.

Uruguay.—Exports of Agate.

Year.	Quantity (kilos.)	Value (£).
1924	98,982	182
1925	5,000	10
1926	81,000	169
1927	78,000	161
1928	22,000	46
1929	42,000	86
1930	124,000	600
1931	78,000	400
1932	33,000	200

Venezuela.*

Diamond has been found in the vicinity of the Cuyuni and Paragua rivers in the State of Bolivar, but exploitation of the deposits is hindered by their inaccessibility.

Emerald is stated to occur near the river Motatan near Mucuchies in the Andes.

Opal has been found near Tinaquillo in the State of Carabobo, and *amethyst* and *garnet* near Carácas.

Afghanistan.

Ruby occurs and has been worked near Jagdalak east of Kabul where it is found in crystalline limestone at the crest of the Siah Koh range. It is accompanied by *garnet* and *spinel.* The ruby mines of Badakshan, situated near the Oxus river in Shignan, were famous in former times, but little is known about them. Spinel is also said to occur abundantly at this locality and the name "balas-ruby" is believed to have been derived from Balascia, the old name for the province.

Afghanistan has from very ancient times been an important source of *lapis lazuli*, a stone which was at one time much more highly prized than it is at present. The mineral is said to occur in a black and white limestone at a remote and almost inaccessible locality in the upper part of the valley of the Kokcha river, a tributary of the Oxus. The method of mining still adopted is the primitive splitting of the rock by heating and quenching. The stone is brought out of the country in the form of lumps weighing up to ten pounds each.

The mines have probably been worked for more than 6,000 years. Lapis lazuli was known to the ancients as sapphire and much of that employed by the jewellers of ancient Egypt and Babylon probably came from Badakshan. At present the exploitation and cutting of the Afghanistan lapis lazuli is stated to be in the hands of German firms. There is a considerable export trade in this mineral to Northern India, where it is made up into jewellery at Lahore.

* Moniteur Officiel du Comm. et de l'Ind., Feb. 11, 1931, p. 582.

China.*

The countries of the former Chinese Empire are not important producers of precious stones, but many occurrences have been noted and several stones are produced.

Diamond is said to occur in Lan Shan Hsien in Shantung Province, but the stones are of no commercial importance.

Sapphire and *ruby* occur in the gravels of several rivers in the west and south-west of Yunnan, but are unimportant. The pink corundum of Ping Shan in Chihli is too opaque for gem purposes, but is used in jade cutting. Ruby is said to occur in the Hei-tsiang-hsien district on the eastern slopes of the Yan-tung-shan in the Heilungkiang Province of Manchuria.

Nephrite and *jadeite* are by far the most highly prized stones, and China is the most important market for them. Both these minerals, together with several other green semi-opaque stones such as prehnite and green avanturine, are known as " Yu " and are divided into several categories according to colour and appearance, but only nephrite is produced in the country. It occurs principally in the south and west of Sinkiang (Eastern Turkestan) along the northern slopes of the Kuen Lun range and has been worked at numerous localities, especially in the valleys of the Karakash, Yurungkash and Keriya rivers. At present the chief districts are Ho-tien and Yu-tien (Khotan). It is said to form a layer 20 to 40 feet thick between hornblende-schist and gneiss and has in the past been quarried *in situ*, but most of the material is obtained in the form of boulders from the river beds. A new deposit which is said to be important has recently been discovered in the Yeung-kong district about 120 miles S.W. of Canton.†

Nephrite of many diverse types is carved into ornaments, the colours being white, green, blue, turquoise, yellow and black, but the white is most frequently used and is highly esteemed. Jadeite, which is brought into the country from Burma, is more valuable than nephrite when it is of the bright green variety; it is used mainly for small articles, while nephrite is used for larger ornaments.

Canton is the important market for crude material, which is sold by weight. Sales take place only once a year, each piece being separately numbered and sold by a kind of auction with a system of secret bidding.

---

* General statement on the mining industry (1918–1925), by C. Y. Hsieh ; Special Rept. No. 2, Geol. Surv. China, 1926, [in Chinese], (Precious stones, pp. 336–8). The jade industry in China, by E. S. Cunningham ; Commerce Reports, U.S. Dept. Comm.), March 17, 1930, pp. 692–4.

† U.S. Foreign Trade Notes, No. 367, Dec. 12, 1931, p. 5.

The cutting and carving industry is carried on mainly at Canton, Peking, Soochow and Shanghai, and in spite of the use of primitive implements the work done by Chinese carvers greatly surpasses that accomplished anywhere else in the world. Besides jade many other stones are carved such as chrysoprase, beryl, emerald, quartz and tourmaline, most of which are imported in the crude state. More than 600 establishments of various sizes are engaged in the jade trade in Peking. Jade cutting is also a staple industry in Têng-yüèh in Yunnan.

Beryl and *topaz* are said to be obtained in the Ta Ching Mountains of Sui yuan, and aquamarine at Tzu Ching Kuan in I Hsien in Chihli.

Tourmaline is reported to be obtained at several localities in Yunnan, notably at Teng Chung Hsien and Ilan.

Varieties of *quartz* are obtained in very many parts of China, but production is largest in the Tung Hai district of Kiangsu. *Amethyst* is obtained at I Hsien and in the Tzu Ching district in Chihli as well as at Wu-tai-shan in Shansi. *Cairngorm* is obtained in considerable quantities in the Great and Small Hingan mountains of Manchuria, where it is often known as " topaz," and is also found in the Yung Yuan district of Hunan. *Smoky quartz* is produced at Lao Shan in the Hei Hsien district of Shantung, in the Hsin Yang district of Honan and at Shanshan in Sinkiang. Many varieties of *carnelian*, *agate*, etc., are also produced, the chief sources being in the Chin Hsien area in Fengtien, and beyond Chang-chia-kou in Chihli. They are also produced at Lin-ju in Honan, I-tu in Hupei, Hsu-i in Anhui, and Liu-ho in Kiangsu.

In Chinese trade returns precious stones are not separately recorded, but the amount of jadeite and nephrite imported is said to amount to more than 6,000 tons a year.

Indo-China.*

The important precious stone of Indo-China is *sapphire*, but it is not generally known as the produce of that country, being exported to Siam via Chantabun and sold in Europe as Siamese sapphire.

The deposits are in the alluvium of the Pailin stream, a tributary of the Nam Mong in Cambodia, close to the frontier, and about 170 miles E.S.E. of Bangkok. The workings are at Boyaka and Bodinheo, and the industry is in the hands of a colony of Burmese. The gem gravels are of very limited extent and are said to be

* Bull. écon. de l'Indochine, No. 162, 1923, p. 406. La géologie et les mines de l'Indochine française, by F. Blondel; Paris, 1932.

becoming exhausted, although formerly they were the chief source of sapphire in the world. The gemstones are concentrated by washing in a current of water, followed by hand washing in baskets. In addition to sapphire, some *zircon* and *ruby* are obtained.

A few stones are also obtained in the Ban Houei Sai district on the Upper Mékong.

Indo-China—Production of Precious Stones (chiefly Sapphire).

Year.	Quantity (carats).	Year.	Quantity (carats).
1919	2,853	1926	3,237
1920	3,413	1927	3,087
1921	3,480	1928	2,631
1922	4,719	1929	2,232
1923	4,888	1930	630
1924	4,144	1931	1,300
1925	5,240	1932	3,976

Japan.*

Precious stones do not form an important item in the Japanese mineral industry. Ruby, sapphire and beryl of gem quality are known to occur in unimportant quantity, and occurrences of tourmaline, garnet, agate, etc. have been recorded, but topaz and various forms of quartz are more abundant.

Topaz has been obtained in some quantity near Takayama and Naegi in Mino Province and Tanokamiyama in Omi Province and in less amount from Ishigure in Ise Province and Hosokute in Mino Province. It occurs in pegmatite veins in granite rocks and with cassiterite in river deposits derived from them. The colour varies from brown to pale yellow, and blue, green, colourless and parti-coloured stones are met with. According to T. Wada, the brown and brownish-yellow varieties lose their colour gradually on exposure to light, becoming blue and ultimately colourless, but the transition is not uniformly rapid in all directions in the crystal.

The principal localities for transparent *beryl* are near Ishikawa in Iwaki Province, Takayama and Tanokamiyama.

Rock crystal from the granitic region around Mt. Kimpu in Kai Province has been worked for ornamental purposes for centuries, but fine crystals occur in many other localities. *Amethyst* of fine quality occurs at Tsunagi in Echigo Province and Fujiya in Hoki Province, and *rose quartz* at Goto in Iwaki Province. A green *jasper* or *plasma* occurring at Yumachi, Izumo Province, has been used for ornaments.

* **Minerals of Japan, by T. Wada, translated into English by T. Ogawa; Tokio, 1904.**

Netherlands East Indies.*

The only precious stone of importance occurring in these islands is the *diamond* of Borneo, and although stones are reported to have been found in many parts of the island, there are only two districts in which economic deposits appear to exist. These are the Landak district in the extreme west near Pontianak, and the area around Martapoera near Bandjermasin in the south-east.

In both districts the diamond is found only in alluvial deposits, some of which take the form of gravel terraces made up of the detrital material washed down by ancient rivers, while others are recent river deposits. The primary source of the gems is entirely unknown, none having been found in any of the older rocks of the island.

In the western district the principal deposits are found in the vicinity of the Landak river and its tributaries, especially in the upper reaches of the river; in the upper reaches of the Sekajam; and along the Kapoeas river, especially near Sanggau.

In the south-eastern district, which is the more important producing area, the principal workings are near Tjampaka on the Banjoe Irang river, and near Mali-Mali and Pingaran on the Riam Kanan, while there are numerous other occurrences along these rivers and also on the Riam Kiwa. Near the coast there are deposits in the Sebamban, Angsana, Boenati and Satarap rivers.

Scattered finds have also been made at various places in the south of the island, especially in the basins of the Kotawaringin and Pembuan rivers.

The industry is of great antiquity and has always been in the hands of natives and Chinese, who work the deposits in primitive fashion. The gravel usually consists of well-rounded quartz pebbles and rock fragments in a clayey matrix, corundum and brookite forming the bulk of the heavy concentrate. Shafts about 4 or 5 feet square, lined with saplings and grass, are sunk into the deposits sometimes to a depth of 30 feet, water being baled out by means of cans. The work is done with amazing rapidity. Gravel is loosened by means of short crowbars and passed from hand to hand up the shaft in baskets to be piled at the surface. It is then placed in a native canoe, water added, and two natives (who sit at either end of the boat) pedal the wash backwards and forwards with their bare feet, at the same time picking out and throwing away the larger pebbles. The puddled gravel is then sieved and finally

* Borneo: its geology and mineral resources, by T. Posewitz, (translated by F. H. Hatch); London, 1892, pp. 381–406. Bijdrage tot de kennis van den oorsprong en de verspreiding der diamanthoudende afzettingen in Zuidoost-Borneo en van de opsporing en winning van den diamant, by L. H. Krol; Jaarboek van het Mijnwezen in Nederlandsch-Oost-Indië, 1920 (1922), 49, Pt. 1, pp. 250–304. Diamonds in Dutch Borneo, by A. S. Wheler and J. H. Foran; Mining Mag., 1923, 29, 9–13.

concentrated by washing in native bateas. The worker stands waist-deep in water, rocking the batea and rabbling the wash with his free hand, the operation being accomplished with great dexterity. Diamond is picked out by hand from the concentrate.

The stones obtained are of good shape and quality, but small, averaging about 4 to the carat, large stones being occasionally met with. A few coloured stones are found.

The bulk of the stones are cleaved and cut locally. Prior to the war several mills were in operation, more than half the output consisting of South African stones imported in the rough, but at present there are two large mills of 60 spindles each in operation in Martapoera, working almost entirely on local stones.

The cut stones are absorbed principally in Eastern markets since the style of cutting employed is not that which is appreciated in Western countries, where stones must be cut to secure the maximum of brilliance. Only the larger stones sometimes find their way to Europe and America and these have to be recut.

The diamond output of Borneo appears to have declined considerably in recent years.

Among world-famous stones the *Matan*, which is said to have come from the Landak mines in 1787, is sometimes included. It is said to weigh 376 carats and to be uncut, but there is some doubt as to whether it is really a diamond.

Persia.

Persia is famous for *turquoise*, of which it has been a producer for many centuries. The principal source is a mountainous tract some 30 miles from Nishapur in the province of Khorasan. The turquoise fills crevices in a weathered porphyritic trachyte, and is associated with limonite. As a rule it occurs as thin layers between layers of limonite, but sometimes it is found as small irregular masses. It sometimes forms pseudomorphs after felspar in the trachyte, and is also found in detrital deposits accumulated at the foot of mountain slopes.

Many hundreds of mines have been worked in this area but most of them have now been abandoned. The stones were taken to the market at Meshed and ultimately found their way to the outside world via Russia. Under an old law no stones may be exported unless mounted; the best ones are therefore set in gold, the next quality in silver, lower grade stones in tin rings and the lowest grade in paper ornaments.

At the present time the great bulk of the exports of turquoise goes to India.

Persia.—Exports of Turquoise.

Years ended March 21.	Matrix turquoise.		Cut turquoise.	
	Quantity. (kilos).	Value. (£).	Quantity. (kilos).	Value. (£).
1928–29	1,830	1,331	1,325	5,709
1929–30	1,734	1,083	1,604	6,948
1930–31	909	60	2,014	5,396
1931–32*	644	369	1,625	19,354

* Year ended June 21, 1932.

Siam.*

Sapphire and *ruby* have been obtained from alluvial deposits in the districts of Chantabun and Krat in the south-east coastal area, the workings being situated near the villages of Nawang, Chanma, and Ban Yet. The unhealthy character of the climate has been a bar to European enterprise, and practically all the workings are in the hands of Burmese, but the industry does not appear to have been of much importance in recent years.

In 1921 an occurrence of sapphire was recorded in the province of Kanburi; two permits were granted to work the deposit, but up to 1929 only about 7,000 carats had been produced there. More recently it has been reported that since the middle of 1927 sapphire of high quality has been produced in the Bo Poi mining area of south Siam, but the situation of this deposit is obscure.

There is a considerable export trade in precious stones from Siamese ports, but most of the stones emanate from Indo-China. Sapphire is the principal stone.

For some years a beautiful blue variety of *zircon* has been sold in all the world's markets. It has received the name " starlite " and comes from the old sapphire deposits of south Siam, but is not quite a natural product. The zircon as found is of a brownish colour, and the blue colour is stated to be produced by some process of heating.

Siam.—Exports of Sapphire and Ruby.

Value (£).*

Years ended March 31	Sapphire.	Ruby.
1927-28	20,600	1,300
1928-29	14,100	300
1929-30	3,500	1,500
1930-31	12,300	1,200
1931-32	8,400	500

* Converted at £1=11 Baht.

* Commercial Directory for Siam, Ministry of Commerce and Communications Bangkok; 3rd Edit., 1929, p. 57.

REFERENCES TO TECHNICAL LITERATURE.

GENERAL.

Precious stones, by Max Bauer, translated with additions by L. J. Spencer; London, 1904, 627 pp.
Les pierres précieuses, by J. Escard; Paris, 1914, 459 pp.
Gemstones and their distinctive characters, by G. F. H. Smith; London, 1919, 312 pp.
The jewel house, by Sir G. Younghusband; London, 1921, 256 pp.
Gems and precious stones; U.S. Geol. Surv. Min. Res. (discontinued in 1921).
Handbook of gems and precious stones, by G. P. Merrill and others; U.S. Nat. Museum Bull. 118, 1922.
The geologic and geographic occurrence of precious stones, by S. H. Ball; Econ. Geol., 1922, **17**, 575-601.
The coloring and thermophosphorescence produced in transparent minerals and gems by radium radiation, by S. C. Lind and D. C. Bardwell; Journ. Franklin Inst., 1923, **196**, 375.
Precious stones; a guide to the Townshend Collection, by Sir A. H. Church; London, Victoria and Albert Museum Handbook, 5th Edit., 1924, 164 pp.
Gems and gem materials, by E. H. Kraus and E. F. Holden; New York, 2nd edit., 1931, 260 pp.
Marketing of precious stones, by G. F. Kunz; Eng. Min. Journ.-Press, 1925, **119**, 361-370.
Die weltwirtschaftliche Bedeutung der Edelsteine, by M. Meisner; Internat. Bergwirts., 1928, **3**, 209-211.
Le pietre preziose, by U. Mannucci; Milan, 1929, 401 pp.
Precious and semi-precious stones, by M. Weinstein; London, 1929, 138 pp.
Mineral determination by absorption spectra (part 2), by E. T. Wherry; Amer. Min., 1929, **14**, 323-328.
Precious stones, by G. F. Kunz; Min. and Met., 1930, **11**, 40-41.
Historical notes on gem mining, by S. H. Ball; Econ. Geol., 1931, **26**, 681-738.
The gemmologist (Journ. Gemmological Assoc.); London, monthly from Aug. 1931.
Precious and semi-precious stones, by G. F. Kunz; The Mineral Industry (Annual).
Edelsteinkunde, by Max Bauer, 3rd edit. by K. Schlossmacher; Leipzig, 1932, 871 pp.

DIAMOND.

Prospecting and washing for diamonds, by W. J. Dick; Trans. Canad. Min. Inst., 1913, **16**, 289-294.
Cutting and polishing diamonds mechanically, by S. Schenken; S. Afr. Journ. Ind., 1921, **4**, 875.
Die Diamantlagerstätten der Welt, by P. Range; Zeits. f. prakt. Geol., 1923, **31**, 49-55, 65.
The coloring of the diamond by radium radiation, by S. C. Lind and D. C. Bardwell; Journ. Franklin Inst., 1923, **196**, 521.
Industrial uses of diamonds, by S. H. Ball; Eng. Min. Journ.-Press, 1925, **119**, 847-850.
L'emploi du diamant pour le sondage au diamant et le forage des trous de mine, by D. de Chahnazaroff; Les Matières Grasses, 1925, **17**, 7151-7152, 7212-7213.
Diamond mining in 1925, by S. H. Ball; Eng. Min. Journ.-Press, 1926, **121**, 925-927.
Over 5½ million carats of diamonds mined in 1926: a review of the industry, by S. H. Ball; Eng. Min. Journ., 1927, **124**, 45-48.

Diamond market's position and outlook; Min. Ind. Mag., 1927, **3**, 403 and 405.
The story of the diamond; Min. Ind. Mag., 1927, **5**, 63, 135-136, 177, 179.
Diamond dies for wire drawing; Metal Ind., 1927, **30**, 65-67.
A study in diamond prices, by S. H. Ball; Eng. Min. Journ., 1927, **124**, 210-212.
Der Diamant, by E. Krenkel; Naturwiss., 1927, **15**, 549-558. Note Chem. Zentralbl., 1927, **98**, Bd. II, 1141.
Industrial carbon, by C. L. Mantell; London, 1928 (Diamond, pp. 7-23).
Industrial diamonds, by R. C. Rowe; Canad. Min. Journ., 1928, **49**, 14.
Diamond: a descriptive treatise, by J. R. Sutton; London, 1928, 118 pp.
The diamond industry in 1928, by S. H. Ball; Eng. Min. Journ., 1929, **127**, 680-681.
Famous diamonds, by O. C. Farrington; Field Museum of Nat. Hist., Geol. Leaflet 10, Chicago, 1929, 27 pp.
The geography of the diamond, by R. R. Walls; Scottish Geogr. Mag., 1929, **45**, 193-205.
Industrial uses of the diamond; S. Afr. Min. Eng. Journ., 1930, **41**, Pt. 2, 269-271.
A simple diamond saw, by J. W. Vanderwilt; Econ. Geol., 1930, **25**, 222-224.
Present day practice of diamond mining, including recovery, by A. F. Williams and J. Harbottle; Proc. 3rd (Triennial) Empire Min. Met. Congress (S. Africa), 1930, Part 3, No. 1, 20 pp.
African bort attains increasing use in diamond drilling, by J. Hanifen; Eng. Min. World, 1931, **2**, 182-183.
L'emploi du diamant dans les sondages, by M. Vignat; Communication to Internat. Boring Congress. Abstr. Echo des Mines, May 20, 1931, pp. 431-433.
Abrasive and industrial diamonds, by P. M. Tyler; U.S. Bur. Mines Inform. Circ. 6562, 1932, 25 pp.
Der Diamant am Ende seiner Herrschaft; Vorkommen, Verwendung und Marktlage, by P. Krusch; Zeits. f. prakt. Geol., 1932, **40**, 65-71.
The genesis of the diamond, by A. F. Williams; London, 1932. (Two vols., 636 pp.).

Ruby and Sapphire.

Rubies and sapphires, by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6471, 1931, 11 pp.
Sapphires, by J. W. Howard; Journ. Chem. Education, 1931, **8**, 613-624.

Beryl, Emerald and Aquamarine.

Béryls hors de Madagascar; Bull. des Mines de Madagascar, No. 18, 1924, pp. 94-96.
Plant for production of beryl emeralds at Somerset mine; S. Afr. Min. Eng. Journ., 1929, Pt. 1, **40**, 621-622.
Beryllium and beryl, by A. V. Petar; U.S. Bur. Mines Inform. Circ. 6190, 1929, 20 pp.
Notes on beryllium and beryl, by H. S. Spence; Mines Branch Canada, Memo. Series 40, 1930, 16 pp.
Emeralds, by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6459, 1931, 18 pp.

Quartz, Amethyst, Agate, etc.

Die Achate, by R. E. Liesegang; Dresden and Leipzig, 1915, 118 pp.
Le cristal de roche; Bull. des Mines de Madagascar, 1924, No. 17, pp. 65-71.
Agate, by O. C. Farrington and B. Laufer; Field Mus. Nat. Hist., Chicago, Geol. Leaflet 8, 1927, 36 pp.

Technology and uses of silica and sand, by W. M. Weigel; U.S. Bur. Mines Bull. 266, 1927 (Agate, pp. 180-181, 184).
Quartz and silica, by R. M. Santmyers; U.S. Bur. Mines Rept. Inv. 6473, 1931 (Agate, pp. 7-8).
Quartz gem stones, by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6561, 1932, 15 pp.

OTHER GEMSTONES.

The story of jade; Chinese Econ. Journ., No. 1, 1927, **1**, 1-21.
Jadeite, by J. Coggin Brown; Rec. Geol. Surv. India, 1930, **64**, 146-154.
Turquoise, by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6491, 1931, 17 pp.
Tourmaline, by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6539, 1931, 8 pp.
Topaz, by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6502, 1931, 11 pp.
Garnets (gemstones), by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6518, 1931, 11 pp.
Feldspar gems (Amazon stone, moonstone, sunstone, etc.), by I. Aitkens; U.S. Bur. Mines Inform. Circ. 6533, 1931, 10 pp.
Zircon: (the gem), by E. P. Youngman; U.S. Bur. Mines Inform. Circ. 6465, July, 1931, 20 pp.
The book of amber, by G. C. Williamson; London, 1932, 268 pp.
The story of opal, by G. F. Shepherd; Rocks and Minerals, 1933, **8**, 1-8. (Opal glossary and bibliography; *ibid.* pp. 43-60).

ARTIFICIAL GEMSTONES.

The formation of diamond, by Sir Charles Parsons; Journ. Inst. Metals, 1918, **20**, 5-24.
The Japanese artificially induced pearl, by H. L. Jameson; Nature, 1921, **107**, 396-398.
Synthetic gems and their technical application, by A. Weiner; Zeit. Instr., 1925, **45**, 579. Abstr. Journ. Soc. Glass Techn., 1926, **10**, 21A.
Synthetischer Türkis, by M. K. Hoffmann; Fortschr. d. Mineral., Krystallogr., Petrogr., 1927, **12**, 45. Note in Chem. Zentralbl., 1928, **99**, Bd. 1, 832.
Die künstlichen Edelsteine, by H. Michel; Leipzig, 2nd edit., 1926, 477 pp.
The problem of artificial production of diamonds; Nature, 1928, **121**, 799-800.
Morphologische und physikalisch-chemische Untersuchungen an synthetischen Spinellen als Beispielen unstöchiometrisch zusammengesetzter Stoffe, by F. Rinne; Neues. Jahr. Min., Abt.A., 1928, **58**, 43-108.
Artificial gem-stone isomorphous with spinel, by P. F. Kerr; Amer. Min., 1929, **14**, 259-264.
Synthetische Edelsteine, by F. Krauss; Berlin, 1929, 134 pp.
L'examen des saphirs naturels et artificiels aux rayons X; Chimie et Ind., 1929, **22**, 636.
Use of cathode rays to detect synthetic sapphires; Min. and Met., 1929, **10**, 489.
Commercial production of diamonds predicted, by J. W. Hershey; Address to Amer. Chem. Soc. Abstr. Eng. Min. Journ., 1929, **128**, 740.
Concerning the artificial preparation of diamonds, by L. Sesta; Phil. Mag., 1929, ser. 7, **7**, 488-493.
Synthetic corundum for jewel bearings, by E. G. Sandmeier; Journ. Inst. Elect. Eng., 1933, **72**, 505-514.

GEMSTONES IN THE BRITISH EMPIRE.

BRITISH ISLES.

Economic geology of Ireland, by G. H. Kinahan; London 1889, (Beryl and topaz, pp. 80-83).
The geology of North Ayrshire, by J. E. Richey and others; Mem. Geol. Surv. Scotland, 1930, Expl. of Sheet 22, 2nd Edn. (Jasper and "Scotch pebble", p. 23).

Gold Coast.

Report on the Mines Department, Gold Coast (Annual).
Report on the Geological Survey, Gold Coast (Annual).
Colonial Reports; H.M. Stationery Office, London (Annual).
The mineral resources of the Gold Coast, by A. E. Kitson; Lecture at Winchester House, London, Nov. 4, 1924. Abstr. Mining Mag., 1925, **32** (Diamond, pp. 13-14).
Outline of the mineral and water-power resources of the Gold Coast, British West Africa, with hints on prospecting, by A. E. Kitson; Geol. Surv. Gold Coast, 1925 (Diamond, p. 35).
Notes on diamond prospecting, Gold Coast Colony, by A. Livingstone Oke; Trans. Inst. Min. Met., 1925-26, **35**, 140-154.
Diamond mining on the Gold Coast, by S. V. Griffith; Mining Mag., 1929, **41**, 271-281.
Diamond recovery from gravels and clays in Gold Coast Colony, by E. D. Candlish; Mining Mag., 1931, **44**, 333-342.
The operation of a diamond concentrating pan, by C. W. Walker; Mining Mag., 1932, **47**, 208-211.
The recovery of alluvial diamonds, by K. McLeod; Mining Mag., 1933, **48**, 9-19.

Sierra Leone.

Rept. Geol. Dept. Sierra Leone, by N. R. Junner; part of 1927 and 1928 (Ruby and Sapphire, p. 16); 1929 (Diamond and Ruby, p. 11).

Southern Rhodesia.

Rept. Secretary for Mines, S. Rhodesia (Annual).
The geology of the diamond-bearing gravels of the Somabula Forest, by A. M. Macgregor; S. Rhodesia Geol. Surv. Bull. 8, 1921, 38 pp.
The Somabula diamond fields; Rhodesian Min. Journ., 1927, **1**, 143.

South-West Africa Territory.

Rept. to the Council of the League of Nations on the administration of South-West Africa (Annual).
Diamond fields of German South-West Africa, by C. W. Boise; Mining Mag., 1915, **12**, 329-340.
The geology and mineral industry of South-West Africa, by P. A. Wagner; Dept. Mines and Ind., U. of S. Afr., Geol. Surv. Mem. 7, 1916 (Diamond, pp. 94-107).
Rept. Dept. Overseas Trade on the conditions and prospects of trade in the Protectorate of South-West Africa; H.M. Stationery Office, London, Cmd. 842, 1920 (Diamond, pp. 25-29).
The alluvial diamondiferous deposits of South and South-West Africa, by F. C. Cornell; Journ. Roy. Soc. Arts, 1921, **69**, 136-147.
On some mineral occurrences in the Namib Desert, by P. A. Wagner; Trans. Geol. Soc. S. Afr., 1921, **24** (Gemstones, pp. 80-92).
The diamond fields of South-West Africa, by J. W. Finch; Eng. Min. Journ., 1922, **113**, 317-321.
Ueber den Ursprung der Achatgerölle und der Gerölle anderer Quarzmineralien in den Diamantseifen an der Küste Südwestafrikas, by W. Beetz; Neues Jahrb. f. Mineralogie, 1923, **47**, 347-380.
Die Entwicklung bergbaulicher Tätigkeit in Deutsch-Südwestafrika, by Dausch; Lecture in Innsbrück, March 2 and 3, 1925. Abstr. Montan. Runds., 1925, **17** (Diamond, pp. 432-433).

Die Diamantenwüste Südwest-Afrikas, by W. Beetz, E. Kaiser and others (Expl. of geol. map of the southern diamond fields), Berlin, 1926, vols. 1 and 2.
Die Diamantlagerstätten Südwestafrikas, by E. Kaiser and others; Berlin, 1926, 2 vols. Abstr. Geogr. Journ., 1927, **69**, 146-148; also Internat. Bergwirts., 1927, **2**, 41-42.
Minerals and mines in S.W. Africa; S. Afr. Min. Eng. Journ., 1927, **38**, Pt. 2, (Diamond, pp. 155-157, 181-182, 225-226, 257-258, 281).

TANGANYIKA TERRITORY.

Report on the administration of Tanganyika Territory (Annual from 1925).
Rept. Mines Dept., Tanganyika Territory, (Annual from 1926).
Rept. Dept. Overseas Trade on the trade and commerce of East Africa, to Sept. 1925 (Diamond, p. 25); 1926-1927 (Diamond, p. 33); to Sept. 1928 (Diamond, p. 31); 1931 (Diamond, p. 41).
Report on the property of Tanganyika Diamonds Ltd., by W. H. Jones; S. Afr. Min. Eng. Journ., 1925, **36**, Pt. 2, 210.
Report on Mwanza property of Tanganyika Diamonds Ltd., by F. A. Unger; S. Afr. Min. Eng. Journ., 1926, **37**, Pt. 2, 207-209.
Note on kimberlite from Tanganyika Territory, by P. A. Wagner; S. Afr. Journ. Science, 1926, **23**, 204-205.
The diamonds at Mwanza; S. Afr. Min. Eng. Journ., 1927, **38**, Pt. 1, 139-141.
Shinyanga diamond fields, by H. S. Harger; Mining Mag., 1928, **39**, 372.
The diamond pipes of Tanganyika, by H. S. Harger; S. Afr. Min. Eng. Journ., 1928, **39**, Pt. 2, 16-17; 1929, **40**, Pt. 1, 569.
Outlines of geology of the regions adjoining the south-eastern shores of Lake Victoria, by F. B. Wade; Geol. Surv. Dept., Tanganyika Territory, Short Paper 1, 1928 (Diamond, p. 20).
Rept. Mines Dept., Tanganyika Territory, 1927 (Garnet, p. 10); 1928 (Garnet, pp. 10-11); 1930 (Garnet, p. 25).
Ann. Rept. Geol. Surv. Tanganyika Territory 1929, by E. O. Teale (Garnet, pp. 6-7 and 28, Moonstone, p. 7); 1930 (Diamond, p. 27).
Notes on the mineral deposits in the Newala-Lindi area: the Luisenfeld garnet deposits, by G. M. Stockley and F. Oates; Geol. Surv. Dept., Tanganyika Territory, Short Paper 7, 1931, pp. 8-11 and 29-31.
L'industrie minière en Afrique méridionale, by F. Leprince-Ringuet and L. Dumas; Ann. des Mines, Paris, 1931, **20**, No. 8 (Diamond, p. 133).
Shinyanga diamond fields, by E. O. Teale; Geol. Surv. Dept., Tanganyika Territory, Short Paper 9, 1931, 39 pp.
The kimberlite and associated occurrences of the Iramba Plateau, by E. O. Teale; Geol. Surv. Dept., Tanganyika Territory, Short Paper 10, 1932, 10 pp.

UGANDA.

The petrography of the ejectamenta from the Katwe Crater and the possible presence of "diamond pipes" in Uganda, by A. W. Groves; Ann. Rept. Geol. Surv. Dept. Uganda Protectorate for 1930, Part 2, pp. 41-42.
Summary of progress, Geol. Surv. Uganda, 1919 to 1929, by E. J. Wayland (Agate, rock crystal, amethyst, rose quartz, p. 29).

UNION OF SOUTH AFRICA.

Diamond.

Rept. Sec. Mines and Industries and Govt. Mining Engineer (Annual).
Report Transvaal Chamber of Mines, Johannesburg (Annual).
Rept. Dept. Overseas Trade on economic and financial conditions in South Africa (Annual).

Yearbook and Directory, S. Afr. Min. Eng. Journ. (Annual).

The diamond fields of Southern Africa, by P. A. Wagner; Johannesburg, 1914, 347 pp. (contains a comprehensive bibliography).

Diamonds from the Molteno beds, by E. H. L. Schwarz; Trans. Geol. Soc. S. Afr., 1916, **19**, 33-35.

The Postmasburg diamond field; S. Afr. Min. Eng. Journ., 1920, **29**, Pt. 2, 125-126 and 151.

Alluvial diamond digging in South Africa, by S. P. Joubert; S. Afr. Journ. Ind., 1921, **4**, 702-712.

The alluvial diamondiferous deposits of South and South-West Africa, by F. C. Cornell; Journ. Roy. Soc. Arts, 1921, **69**, 136-147.

Notes on the mineral productions of the Union and their relation both geographically and geologically, by W. G. Holford (Anniv. address); Proc. Geol. Soc. S. Afr., 1925, **28** (Diamond, pp. 23-24).

Diamond mining in South Africa, by W. L. Honnold; Min. and Met., 1925, **6**, 324-331.

Report on Driehoek diamond mine, by T. Dilks; S. Afr. Min. Eng. Journ., 1926, **37**, Pt. 2, 351.

Western Transvaal diamondiferous alluvials, by J. Endendyk; Min. Ind. Mag. S. Afr., 1926, **3**, 83-87.

The evolution of diamond mining and winning machinery in South Africa, by D. Draper; S. Afr. Min. Eng. Journ., 1927, **38**, Pt. 2, 383-384, 521-522.

On the occurrence of diamonds associated with the chert beds of the dolomite series in the districts of Ventersdorp and Lichtenburg, by D. Draper; Trans. Geol. Soc. S. Afr., 1927, **30**, 57-67.

Note on an occurrence of diamonds near Port Nolloth, by W. A. Humphrey; Trans. Roy. Soc. S. Afr., 1927, **14**, 217-218.

The geology of the country around Vredefort: an explanation of the geological map, by L. T. Nel; Dept. Mines and Ind., U. of S. Afr., 1927 (Diamond, pp. 114-115).

The mineral wealth of the Union, by T. G. Trevor; Industrial Development in S. Afr., Pretoria, 1927 (Diamond, pp. 161-169).

A unique alluvial diamond recovery plant at Welverdiend; S. Afr. Min. Eng. Journ., 1928, **38**, Pt. 2, 547-548.

The diamond cutting industry; Min. Ind. Mag. S. Afr., 1928, **6**, 303.

First report of the select committee on public accounts (diamond cutting agreement); Cape Town, 1928, 187 pp.

Die Minerallagerstätten Afrikas, ihre Entwicklung und ihre weltwirtschaftliche Bedeutung, by Landschütz; Internat. Bergwirts., 1928, **3** (Diamond, pp. 147-148).

The discovery of the Namaqualand diamonds, by E. Reuning; Min. Ind. Mag. S. Afr., 1928, **7**, 51-55, 87-91, 177-179, 219-221, 265-267, 341-356; 1929, **7**, 435, 437-439.

Some reflections upon a geological comparison of South Africa with South America, by A. L. Du Toit; Proc. Geol. Soc. S. Afr., 1928, **31** (Diamond, pp. 25-30).

The diamond deposits on the coast of Little Namaqualand, by P. A. Wagner and H. Merensky; Trans. Geol. Soc. S. Afr., 1928, **31**, 1-41.

The birth of the diamond industry in South Africa, by D. Draper; S. Afr. Min. Eng. Journ., 1929, **40**, Pt. 1, 675-677 and weekly to 1930, Pt. 2, pp. 570-572.

The geology of the country surrounding Pretoria, by H. Kynaston (Revised by L. J. Krige and others); Dept. Mines and Ind., U. of S. Afr., Expl. of Sheet 1, 1929 (Diamond, pp. 33-34).

The geology of the Postmasburg manganese deposits and the surrounding country, by L. T. Nel; Dept. Mines and Ind., U. of S. Afr., Expl. of geol. map, 1929 (Kimberlite pipes, pp. 50-52).

Recent diamond prospecting in South Africa, by A. L. Du Toit; Econ. Geol., 1930, **25**, 653-657.

Diamond-bearing alluvial gravels of the Union of South Africa, by A. F. Williams; Proc. Third (Triennial) Empire Min. Met. Congress S. Afr., 1930, Part 3, 169 pp.
L'industrie minière en Afrique méridionale, by F. Leprince-Ringuet and L. Dumas; Ann. des Mines, Paris, 1931, **20**, No. 8, Series 12 (Diamond, pp. 116-129).
Production, sales and stocks in the South African diamond industry, by G. A. Roush; Min. Journ., 1932, **179**, 660-662.

Beryl and Emerald.

Transvaal emeralds; S. Afr. Min. Eng. Journ. Year Book 1928, pp. 585-588. Also S. Afr. Min. Eng. Journ., 1928, **39**, Pt. 1, 101-103.
The African beryl and emerald mines, by S. A. Ball; S. Afr. Min. Eng. Journ., 1928, **39**, Pt. 1, 629.
Remarkable beryl discovery; S. Afr. Min. Eng. Journ., 1929, **40**, Pt. 1, 461 and 477-480.
The Barbara beryls; a study of an occurrence of emeralds in the north-eastern Transvaal, by J. M. le Grange; Trans. Geol. Soc. S. Afr., 1929, **32**, 1-25.
The position of the Beryl Mining Co.; S. Afr. Min. Eng. Journ., 1930, **41**, Pt. 1, 470-471.
The emerald industry of the Transvaal; Min. Ind. Mag. S. Afr., 1930, **11**, 107, 109, 185.

Other Gemstones.

On olivine rocks and serpentines of the Bushveld complex, by P. A. Wagner; Trans. Geol. Soc. S. Afr., 1923, **26** (Opal, pp. 22-27).
On "jade" (massive garnet) from the Bushveld in the western Transvaal, by A. L. Hall; Trans. Geol. Soc. S. Afr., 1924, **27**, 39-55.
Gems and precious stones in South Africa, by G. W. Bond; Min. Ind. Mag. S. Afr., 1928, **6**, 155-156.

CANADA.

Mineral deposits between Lillooet and Prince George, British Columbia, by L. Reinecke; Geol. Surv. Canada, Mem. 118, 1920 (Peridot, pp. 81-84).
Northeastern part of Labrador and New Quebec, by A. P. Coleman; Geol. Surv. Canada, Memoir 124, 1921 (Labradorite, p. 50).
The resources of Nova Scotia; Nat. Resources Intellig. Service, Ottawa, 1923 (Amethyst, p. 36).
The blue corundum of the Bancroft area, by H. V. Ellsworth; Canad. Min. Journ., 1924, **45**, 1009-1010.
The non-metallic mineral resources of Manitoba, by R. C. Wallace and L. Greer; Ind. Development Board of Manitoba, 1927 (Rose quartz, p. 54).
Extracts from reports on the district of Ungava or New Quebec; Bur. Mines, Province of Quebec, 1929 (Gemstones, pp. 109-110).

NEWFOUNDLAND.

Northeastern part of Labrador, and New Quebec, by A. P. Coleman; Geol. Surv. Canada, Mem. 124, 1921 (Labradorite, p. 47).

BRITISH GUIANA.

Diamond.

Ann. Report Lands and Mines Dept., British Guiana.
Colonial Reports; H.M. Stationery Office, London (Annual).
Diamond fields of British Guiana, by L. T. Emory; Eng. Min. Journ.-Press, 1923, **115**, 571-575.

Report of the preliminary survey of the Mazaruni and Puruni diamond fields, British Guiana, March-Dec., 1925, Part 1, by H. J. C. Conolly; Dept. Science and Agric., Econ. Geol. Surv. Crown Agents for the Colonies, 103 pp.

Report on the preliminary geological survey of the Potaro-Ireng district of British Guiana, by S. Bracewell; Combined Court No. 21, Georgetown, Demerara, 1926 (Diamond, pp. 4-5 and 34-36).

Interim report and statement of policy of the Geological Survey, by H. J. C. Conolly; Combined Court No. 3, Georgetown, Demerara, 1927 (Diamond, pp. 2-3 and 5-6).

The alluvial diamonds of British Guiana, by J. H. Mitchiner; Mining Mag., 1927, **36**, 73-83.

The Potaro diamond district, British Guiana, by S. Bracewell; Mining Mag., 1928, **38**, 267-276.

Report on the recent geological investigations in the Potaro River district, by H. J. C. Conolly and S. Bracewell; Legislative Council No. 9, Georgetown, Demerara, 1928 (Diamond, pp. 2-3 and 10).

Report of the diamond and gold industries Commission; Legislative Council No. 10, Georgetown, Demerara, 1928, 46 pp.

Report on the Buck Canister—Oranapai section of the Mazaruni diamond field; Legislative Council No. 10, Georgetown, Demerara, 1930, 18 pp.

CEYLON.

Ceylon Administration Reports, Part IV (Min. Surv.), by A. K. Coomaraswamy and J. Parsons; 1903, p. 10; 1904, pp. 11-19; 1905, pp. 10-12; 1906, pp. 6-8; 1907, p. 8.

Colonial Reports; H.M. Stationery Office, London (Annual).

Fibrolite as a gemstone from Burma and Ceylon, by L. J. Spencer; Mineralog. Mag., 1920, **19**, 107-112.

Report of the Committee appointed to report upon the gemming industry in Ceylon; Colombo, 1921, 8 pp.

Note on the sources of origin of Ceylon gemstones, by E. J. Wayland; Econ. Geol., 1923, **18**, 514-516.

Gems and minerals: Ceylon Committee for the British Empire Exhibition, 1924, 16 pp.

A visit to the gem districts of Ceylon and Burma, by F. D. Adams; Bull. Canad. Inst. Min. Met., Feb., 1926, pp. 213-246.

A contribution to the study of moonstone from Ceylon, by E. Spencer; Mineralog. Mag., 1930, **22**, 291-376.

INDIA.

Review of the mineral production of India; Rec. Geol. Surv. India (Annual and Quinquennial).

Ann. Report Chief Inspector of Mines.

Note on the mineral production of Burma; Rangoon (Annual).

Mineral resources of Bihar and Orissa, by L. L. Fermor; Patna, 1921 (Gemstones, pp. 21-22).

Notes on Indian precious stones, by C. S. Fox; Journ. Indian Ind. and Labour, 1921, **1**, Part 3, 304-326.

Limestones, iron ores, ochres, fireclay deposits, etc., by K. P. Sinor; Geol. Dept. Rewa State, Bull. 4, 1923 (Gems, pp. 51-52).

The mineral deposits of Burma, by G. de P. Cotter; Rangoon, 1924 (Gem stones, pp. 20-23 and 25-27).

A visit to the gem districts of Ceylon and Burma, by F. D. Adams; Bull. Canad. Inst. Min. Met., Feb., 1926, pp. 213-246.

Burma—an important source of precious and semi-precious gems, by A. B. Calhoun; Eng. Min. Journ., 1929, **127**, 708-712.

The gemstones of the Himalaya, by A. M. Heron; Himalayan Journ., 1930, **2**, 21-28. Note Trans. Min. Geol. Inst. India, 1931, **25**, 374

Gemstones of lesser importance, by E. H. Pascoe; Rec. Geol. Surv. India, 1930, **64**, 385-392 and 423-424.

Mineral resources of Madras, Mysore and Travancore, by V. S. Swaminathan; Trans. Min. Geol. Inst. India, 1930, **25**, Part 2 (Gemstones, pp. 124-126).

Precious and semi-precious gemstones of Jammu and Kashmir, by C. S. Middlemiss; Jammu and Kashmir, Min. Surv. Rept. 9, 1931, 58 pp.

Diamond.

A history of the Golconda diamond mines, by L. Munn; Journ. Hyderabad Geol. Soc., 1929, **1**, Part 1, 21-62.

The diamond-bearing tracts of Anantapur district, Madras, by L. L. Fermor; Rec. Geol. Surv. India, 1931, **65**, 39.

Ruby and Sapphire.

Rubies in the Kachin Hills, Upper Burma, by A. W. G. Bleeck; Rec. Geol. Surv. India, 1908, **36**, 164-170.

The material resources of Burma, by Sir H. Adamson; Bull. Imp. Inst., 1918, **16** (Ruby, pp. 74-75).

Notes on a visit to the Burma ruby mines, by R. R. Simpson; Trans. Min. Geol. Inst. India, 1922, **17**, Part 1, 42-58.

Burma ruby mines (Gen. Rept. Geol. Surv. India for 1927); Rec. Geol. Surv. India, 1928, **61**, 53-56.

Ruby mining in Burma, by G. Cecil; Eng. Min. Journ., 1928, **126**, 294.

Ruby mining in Upper Burma, by J. Coggin Brown; Mining Mag. 1933, **48**, 329-340.

Jadeite.

Jadeite in the Kachin Hills, Upper Burma, by A. W. G. Bleeck; Rec. Geol. Surv. India, 1908, **36**, 254-284.

Jade mining in Burma, by C. W. Chater; Trans. Inst. Min. Eng., 1915, **49**, 630-633.

Note sur la genèse de la jadéite de Birmanie, by A. Lacroix; Bull. Econ. de l'Indochine, Renseign., 1928, **31**, 974-978.

Jadeite, Myitkyina district, Burma (Gen. Rept. Geol. Surv. India); for 1928, Rec. Geol. Surv. India, 1929, **62**, 55-57 and 108-114; for 1929 *ibid.* 1930, **63**, 38-42; for 1932, *ibid.* 1931, **66**, 62-63.

Other Gemstones.

Memorandum on the tourmaline mines of Maingnin, by E. C. S. George; Rec. Geol. Surv. India, 1908, **36**, 233-238.

Note on the aquamarine mines of Daso on the Braldu River, Shigar Valley, Baltistan, by C. S. Middlemiss and L. J. Parshad; Rec. Geol. Surv. India, 1918, **49**, 161-172.

Report on the economic mineral deposits in parts of the Hassan district, by P. S. Iyengar; Dept. Mines and Geol., Mysore State, Records, 1919, **18**, Part 2 (Chalcedony and agate, p. 92).

The geology and ore deposits of the Tavoy district, by J. Coggin Brown and A. M. Heron; Mem. Geol. Surv. India, 1923, **44** (Topaz, pp. 223-225).

Amber (Min. Prod. India, 1924-28), by E. H. Pascoe; Rec. Geol. Surv. India, 1930, **64**, 318-320.

Amber in Hukawng Valley, Burma, by L. L. Fermor; Rec. Geol. Surv. India, 1931, **65**, 33-34.

AUSTRALIA.

Rept. Dept. Mines, New South Wales (Annual).
Rept. Under-Sec. Mines, Queensland (Annual).
The Woolshed Valley, Beechworth, by E. J. Dunn; Victoria Geol. Surv. Bull. 25, 1913 (Gemstones, pp. 7-16).
Geology and mineral resources of the Stanthorpe, Ballandean and Wallangarra districts, southern Queensland, by E. C. Saint-Smith; Queensland Geol. Surv. Publ. 243, 1914 (Gemstones, pp. 132-134).
Queensland's precious stones; Mining Mag., 1922, **26**, 271-276.
Description of the gem sands of Encounter Bay, by R. G. Thomas; Trans. and Proc. Roy. Soc. S. Australia, 1923, **47**, 255-258.
The mineral industry of New South Wales, by E. C. Andrews and others; Dept. Mines N.S.W., 1928 (Gemstones, pp. 302-309).
Report of the Royal Commission on the mining industry of Queensland, 1930 (Gemstones, p. 73).

Diamond.

Mineral resources of New South Wales, by E. F. Pittman; Geol. Surv., Sydney, 1901.
Occurrence of diamonds in matrix at Pike and O'Donnell's claim, Oakey Creek, near Inverell, New South Wales, by T. W. Edgeworth David; Compte Rend. Congr. géol. internat., Mexico, 1906, pp. 1201-1210.
The diamond deposits of Copeton, New South Wales, by L. A. Cotton; Proc. Linnean Soc. N.S.W., 1914, **39**, 803-838.
The Bald Hill osmiridium field, by W. H. Twelvetrees; Dept. Mines Tasmania, Geol. Surv. Bull. 17, 1914 (Diamond, p. 38).
Osmiridium in Tasmania, by A. M. Reid; Dept. Mines Tasmania, Geol. Surv. Bull. 32, 1921 (Diamond, pp. 15-16).

Ruby and Sapphire.

Report on the sapphire fields of Anakie, by B. Dunstan; Brisbane, 1902, 26 pp.

Beryl and Emerald.

The occurrence of common and precious beryl at Poona, by E. S. Simpson; Dept. Mines W. Australia, Ann. Progress Rept. Geol. Surv. 1925, appendix 1, p. 177.
The beryl deposits of Poona and Ferndale, by R. C. Wilson; Rept. Dept. Mines W. Australia 1925, appendix 3, pp. 81-83.
Rept. Dept. Mines W. Australia 1927 (Emerald, p. 6); 1928 (Emerald, p. 6); 1929 (Emerald, p. 6).

Opal.

Dept. Mines S. Australia, Mining Reviews (Semi-annual).
Notes on the Stuart's Range opal field, by L. K. Ward; S Australia Mining Rev. No. 25, 1916, pp. 36-44.
The geology and mineral resources of the Yilgarn goldfield, by T. Blatchford, C. S. Honman and others; W. Australia Geol. Surv. Bull. 71, 1917 (Opal, pp. 229-230).
Tintenbar opal field, by M. Morrison; Ann. Rept. Dept. Mines N.S.W. 1919, p. 173.
Opal occurrences in the Springsure district, by E. C. Saint-Smith; Queensland Govt. Min. Journ., 1922, **23**, 188-189.
Geology of the Lightning Ridge (Wallangulla) opal field, by E. C. Andrews; Ann. Rept. Dept. Mines N.S.W. 1924, pp. 84-86.

The Coober Pedy (Stuart's Range) opal field, by L. J. Winton; S. Australia Mining Rev. No. 42, 1925, pp. 72-77; No. 47, 1927, p. 58; No. 54, 1931, p. 108.
Grawin opal field, N.S.W.; Chem. Eng. Min. Rev., 1927, **19**, 412.
The Grawin-Lightning Ridge opal fields, June, 1928, by L. F. Harper; Ann. Rept. Dept. Mines N.S.W., 1928, p. 99.
Report on the White Cliffs opal field, by E. J. Kenny; Ann. Rept. Dept. Mines N.S.W. 1929, pp. 98-100.

Other Gemstones.

Olivines in the Toowoomba basalts, by W. E. Cameron; Queensland Geol. Surv. Publ. 235, 1911, pp. 44-46.

NEW ZEALAND.

The nephrite and magnesian rocks of the South Island of New Zealand, by A. M. Finlayson; Q.J.G.S. 1909, **65**, 351-381.
The mineral deposits of New Zealand (Dunedin Exhibition Handbook), Mines Dept. N. Zealand, 1925 (Semi-precious stones, p. 21).
Minerals and mineral substances of New Zealand, by P. G. Morgan; Geol. Surv. N.Z., Bull. 32, 1927.
Mining in New Zealand, jade; Extract from New Zealand Official Year Book, Wellington, N.Z. (Revised annually).

GEMSTONES IN FOREIGN COUNTRIES.

AUSTRIA.

Das Smaragdvorkommen im Habachtal, by R. Leitmeier; Mitt. Wien. Min. Ges. No. 92, 1930, pp. 11-15.

CZECHOSLOVAKIA.

Die böhmischen Granatlagerstätten, by H. Oehmichen; Zeits. f. prakt. Geol., 1900, **8**, 1-13.
The Czechoslovak Republic, by J. Císař and F. Pokorný; 1922 (Garnet and opal, p. 83).
Das Granatenbergel bei Meronitz und die " böhmischen Granaten ", by J. E. Hibsch; Bilin (Museumsgesellschaft), 1926, 20 pp.

GERMANY.

German agate grinding industry adopts modern methods, by H. Hermanns; Abrasive Ind., 1931, **12**, 40-41. Abstr. Journ. Amer. Ceram. Soc., 1931, **14**, 244.
Ueber Edelopal und Milchopal aus dem Kaiserstuhl, by J. Soellner; Centr. f. Min., 1927 A, pp. 81-82.
Amber mining in Germany, by F. Prockat; Eng. Min. World, 1930, **1**, 150-152.
Precious stones in German industry; U.S. Dept. Comm. Commerce Repts., March 7, 1932, pp. 550-551.

SPAIN.

La zona diamantífera de Carratraca (Málaga), by E. Rubio; Bol. Inst. Geol. de España, 1927, **49**, 249-265.
Estadística minera de España; (" Topaz ") 1928, p. 554; 1929, p. 528; 1930, p. 564.
Los berilos o esmeraldas de Córdoba, by A. C. y Trillo-Figueroa; Revista Minera, 1930, **81**, 157.

U.S.S.R. (Russia).

Preliminary note on the Ural emerald mines, by N. S. Mikhyev; Bull. Soc. oural Sci. nat., 1913, **32**, 80.
Precious stones in the Urals, by C. W. Purington; Mining Mag., 1916, **15**, 24-25.
Precious and coloured stones of Russia, by A. E. Fersmann; Monograph 3, Russian Acad. Sci., Leningrad, vol. 1, 1922, 420 pp.; vol. 2, 1925, 386 pp. [in Russian].
Le gîte de topazes rosées et dorées de Kotchkar dans l'Oural du Sud, by S. S. Smirnov; Mém. Soc. russe min., 1925, Ser. 2, **54**, 3-20.
Siberia: its resources and possibilities, by B. Baievsky; U.S. Dept. Comm., Trade Promotion Series 36, 1926, 69 pp. (Beryl, p. 45).
Review of the gemstone deposits of southeastern Transbaikal, by P. Sushchinsky; Trans. Russ. Inst. Econ. Mineral. and Met. No. 16, 1925. Abstr. Zeits. f. prakt. Geol., 1927, **35**, 91.
The mining industry in Russia; Volkswirts. d. Union d. soz. Sowjet Republiken, June, July, September 1927. Abstr. Zeits. f. prakt. Geol., 1927, **35**, 148-152. (Gemstones, p. 148).
Nouvelles découvertes d'améthystes dans le bassin du Donetz, by P. Kumpan; Bull. Com. Géol. Leningrad, 1927, **46**, 34-35.
Edel- und Halbedelsteine Russlands; Internat. Bergwirts., 1928, **3**, 227-228.
Die Schmuck- und Edelsteine der Sowjetrepubliken, by A. Fersmann; Zeits. f. prakt. Geol., 1929, **37**, 209-216.
Geological explorations in the emerald region of the Urals, by P. Pyatnitzki; Bull. Com. Géol. Leningrad, 1929, **48**, 283-306.

Angola.

Rept. Dept. Overseas Trade on the economic situation in Angola, March 1923 (Diamond, pp. 11-12); June 1925 (Diamond, pp. 11-12); Feb. 1929 (Diamond, pp. 13-14).
The Congo-Angola diamond fields, by S. H. Ball; Mining Mag., 1925, **33**, 118-120.
Companhia de diamantes de Angola; noticia sobre a sua constituição, concessões e trabalhos, by L. de Castro; Bol. da Agencia Geral das Colónias, 1929, **5**, 212-214.
L'industrie minière en Afrique méridionale, by F. Leprince-Ringuet and L. Dumas; Ann. des Mines, Paris, 1931, **20**, No. 8, Ser. 12 (Diamond in Angola, pp. 130-133).
Mechanising operations reduces theft of diamonds in central Africa, by L. J. Parkinson; Eng. Min. World, 1930, **1**, 127-130.
Nas minas de diamantes; Bol. Geral das Colónias, 1932, **8**, 244-253 (including a map).

Belgian Congo.

Rept. Dept. Overseas Trade on the economic situation in the Belgian Congo, July 1924 (Diamond, p. 33); June, 1926 (Diamond, pp. 13-14).
Note sur une visite aux pipes diamantifères des Monts Kundelungu (Katanga), by R. d'Andrimont; Ann. Soc. Géol. Belg., 1913, **40**, Congo Suppl., 8-19.
A propos des diamants du bassin du Kasai, by J. Cornet; Ann. Soc. Géol. Belg., 1913, **39**, Congo Suppl., 73-76.
The development of the Kasai diamond fields, by H. de Rauw (transl. by J. Rousseaux); S. Afr. Min. Eng. Journ., 1922, **33**, Pt. 1, 1729-1730.
Mineral resources of Lower Katanga, Belgian Congo, by G. Trefois and J. H. Rickard; Mining Mag., 1922, **27**, 340-344. (Diamond pp. 343-344).
The diamond fields of the Kasai, Belgian Congo, by Cayen; Paper read at Sixth Internat. Mining Exhibition, London. Abstr. Mining Mag., 1923, **28**, 336-338.

Les exploitations diamantifères du Kasai, by Langsweert; Rev. Univ. Min. Mét., 1923, **66**, 367-398. Note Glückauf, 1923, **60**, 184.
Les gisements diamantifères du Kasai, by H. de Rauw; Rev. Univ. Min. Mét., 1923, **66**, 385-432. Note Glückauf, 1923, **59**, 983.
The Congo-Angola diamond fields, by S. H. Ball; Mining Mag., 1925, **33**, 118-120.
Diamond mining in Central Africa, by A. B. Sabin; Eng. Min. Journ., 1927, **124**, 533-534.
Diamants, lazulite et atacamite du Congo belge, by H. Buttgenbach; Ann. Soc. Géol. Belg., 1929, **52**, Congo Suppl., 65-68.
Les diamants translucides et opaques des gisements de la Bushimaie, by E. Polinard; Ann. Soc. Géol. Belg., 1929, **52**, Congo Suppl., 178-219; 1930, **53**, Congo Suppl., 1-33.
The Kasai diamond fields of the Belgian Congo, by A. E. Brugger; Min. and Met., 1932, **13**, 357-358.

Egypt.

The topography and geology of the Peninsula of Sinai (western portion), by T. Barron; Survey Dept., Egypt, 1907 (Turquoise, pp. 209-212).
Occurrence of turquoise in Sinai Peninsula; Min. Sci. Press, 1919, **119**, 427.
Report on the mineral industry of Egypt; Ministry of Finance, Egypt, 1922 (Gems, pp. 25-26; 37-38).
Preliminary geological report on St. John's Island, by F. W. Moon; Ministry of Finance, Egypt, 1923 (Peridot, pp. 8-9).
Pharoahs mined turquoise in 3200 B.C., by S. H. Ball; Eng. Min. Journ., 1927, **123**, 483-485.
Report of the Department of Mines and Quarries; Ministry of Finance, Cairo, for 1928 (Peridot and emerald, p. 26).
Egyptian gemstones of pre-Ptolemaic days, by S. H. Ball; Jewellers' Circ. (New York), Feb. 23, Apr. 26 and May 3, 1928. Abstr. Mining Mag., 1928, **39**, 129-131.
Notes on the occurrence and origin of turquoise in the Sinai peninsula, by J. C. Davey; Trans. Roy. Geol. Soc. Cornwall, 1929, **16**, 43-65.

French Equatorial Africa.

Compagnie Equatoriale de Mines; Echo des Mines, Aug. 1, 1930 (Diamond, p. 617); July 20, 1931 (Diamond, p. 607).
Diamonds in Equatorial Africa, by J. L. Middleton; Eng. Min. Journ., 1932, **133**, 285.

Madagascar.

Les mines de Madagascar, by F. Bonnefond; Bull. Écon. de Madagascar, 1921, No. 4, pp. 301-327. (Gemstones, pp. 322-324).
Rapport sur le fonctionnement du service des mines en 1920, by Evesque; Bull. Écon. de Madagascar, 1921, No. 2 (Gemstones, pp. 189-190).
Minéralogie de Madagascar, by A. Lacroix, 3 vols., Paris, 1922-3 (Gems, ornamental and industrial stones, Vol. 2, pp. 80-120).
Les richesses minérales de Madagascar, by F. Bonnefond; La Vie Techn., Ind., Agric. et Colon., Special Madagascar No., 1923 (Gemstones, p. 50).
Les mines de Madagascar, by L. Dumas; Lecture at Tananarive, Feb. 25, 1923. Abstr. Bull. des Mines de Madagascar, 1923, No. 4 (Gemstones, pp. 63-64).
Première foire commerciale officielle de Tananarive, 1923, notice minière, by L. Lavila; Tananarive (Gemstones, pp. 6 and 9-10).
L'industrie des pierres précieuses à Madagascar, by L. Lavila; Bull. des Mines de Madagascar, 1923, No. 8, pp. 138-142.
Les pierres précieuses de Madagascar, by A. Lacroix; Lecture to Acad. des Sciences Coloniales. Abstr. Bull. Écon. de Madagascar, 1926, **22**, 54-60.

Mexico.

Gems and precious stones of Mexico, by G. F. Kunz; Trans. Amer. Inst. Min. Eng., 1902, **32**, 55-93.

Reseña acerca de los topacios de Mexico, by E. Wittich and A. Pastor y Giraud; Bol. Soc. Geol. Mexicana, 1912, **8**, 53-59.

Estudio geológico de la zona minera comprendida entre los minerales de Atotonilco el Chico y Zimapan, en el estado de Hidalgo, by T. Flores and others; Inst. Geol. de Mexico, Bol. 43, 1924 (Gemstones, pp. 131-133).

Granates, turmalinas, micas y feldespatos del distrito norte de la peninsula de la Baja California, by T. Flores; Anales del Inst. Geol. Mexico, 1930, **4**, 55-78.

United States.

Gems, jeweller's materials and ornamental stones of California; California State Min. Bur. Bull. 37, 1905, 171 pp.

Gems and precious stones; U.S. Geol. Surv. Min. Res. (discontinued in 1921).

Minerals of California, by H. S. Eakle; California State Min. Bur. Bull. 91, 1922 (Gemstones, pp. 7-8, 87-92, 114, 171, 192-195, 237).

Geology of the De Queen and Caddo Gap Quadrangles, Arkansas, by H. D. Miser and A. H. Purdue; U.S. Geol. Surv. Bull. 808, 1929 (Gemstones, pp. 147-150).

The Mohave desert region, California, by D. G. Thompson; U.S. Geol. Surv. Water-supply Paper 578, 1929 (Gemstones, pp. 36 and 556).

Diamond.

Diamonds in Arkansas, by G. F. Kunz and H. S. Washington; Trans. Amer. Inst. Min. Eng., 1908, **39**, 169-176.

Diamonds in Arkansas, by S. W. Reyburn and S. H. Zimmerman; Eng. Min. Journ., 1920, **109**, 983-986.

Diamond-bearing peridotite in Pike County, Arkansas, by H. D. Miser and C. S. Ross; Econ. Geol., 1922, **17**, 662-674. Also U.S. Geol. Surv. Bull. 735-I, 1923, 44 pp.

Diamond deposits in Arkansas, by G. J. Mitchell; Eng. Min. Journ.-Press, 1923, **116**, 285-287.

Sapphire.

The sapphire mines of Yogo, Montana, by O. W. Freeman; Min. Sci. Press, 1915, **110**, 800-802.

Minor metals and non-metallic minerals of Montana, by J. P. Rowe; Eng. Min. Journ., 1928, **125**, 816-818 (Sapphire, p. 817).

Beryl.

Colorado Bur. Mines, Ann. Rept. for 1930 (Beryl, p. 15).

Huge beryl crystals at Albany, Maine, by E. K. Gedney and H. Berman; Rock Prod., 1929, **32**, 94-95.

Beryl possibilities in New Hampshire, by H. N. Kirk; Rock Prod., 1929, **32**, 49.

Other Gemstones.

Geology and ore deposits of the Courtland-Gleeson region, Arizona, by E. D. Wilson; Univ. Arizona, Bull. 123, 1927 (Turquoise, pp. 51-52, 66-67).

The mineral industry of Alaska; U.S. Geol. Surv. Bull. 810-A, 1927 (Jade, p. 63); Bull. 813, 1928 (Jade, p. 71); Bull. 824-A, 1929 (Jade, p. 80); Bull. 836-A, 1930 (Jade, p. 82); Bull. 844-A, 1931 (Jade, p. 81).

Geology and mineral deposits of southeastern Alaska by A. F. Buddington and T. Chapin; U.S. Geol. Surv. Bull. 800, 1929 (Garnet, pp. 332-333).
Some personal observations on colored tourmalines as found in the State of Maine, by W. B. Moulton; Rocks and Minerals, 1930, 5, 50-51. Ref. U.S. Bur. Mines Inform. Circ. 6539, 1931, p. 8.
Lazulite from Chittenden, Vermont, by C. Palache and F. A. Gonyer; Amer. Min., 1930, **15**, 338-339. Note in Chem. Abstr., 1931, **25**, 1768-1769.
Geology and mineral resources of northwestern Alaska, by P. S. Smith and J. B. Mertie; U.S. Geol. Surv. Bull. 815, 1930 (Nephrite, pp. 345-346).

Argentina.

Breve recopilación de los yacimientos de materias explotables de la República Argentina, by R. Beder; Direcc. Gen. de Minas, Geol. e Hidrol., Buenos Aires, Bull. 26, Series B, 1921 (Gemstones, pp. 24-25).

Brazil.

Diamond.

Brazilian evidence on the origin of the diamond, by O. A. Derby; Journ. Geol., 1898, **6**, 121-146.
The geology of the diamond and carbonado washings of Bahia, Brazil, by O. A. Derby; Econ. Geol., 1905-6, **1**, 134-142.
The diamond fields of Brazil, by H. Pearson; Journ. Roy. Soc. Arts, 1909, **58**, 101-129.
The diamond-bearing highlands of Bahia, by J. C. Branner; Eng. Min. Journ., 1909, **87**, 981-986.
The diamond-bearing deposits of Bagagem and Agua Suja in the state of Minas Geraes, Brazil, by D. Draper; Trans. Geol. Soc. S. Afr., 1911, **14**, 8-19.
Zur Geologie der diamantführenden Gebiete Brasiliens, by E. Rimann; Zeits. f. prakt. Geol., 1915, **23**, 168-169.
The geology of central Minas Geraes, Brazil, by E. C. Harder and R. T. Chamberlin; Journ. Geol., 1915, **23**, 341-378, 385-424.
The mineral deposits of South America, by B. L. Miller and J. T. Singewald; New York, 1919 (Diamond etc., Brazil, pp. 207-215; bibliography, pp. 218-232).
The high level diamond-bearing breccias of Diamantina, Brazil, by D. Draper; Trans. Geol. Soc. S. Afr. 1920-21, **23**, 43-51; and 1923, **26**, 7-12.
Sur la nature du conglomérat diamantifère de Diamantina (Brésil), by Brouwer; Comptes rend. Acad Science, 1920, **171**, 402-404. Ref. Rev. de Géol., 1921, **2**, 163.
Relatorio do Serviço Geologico; Ministerio da Agric., Ind. e Comm., Rio de Janeiro, 1921 (Diamond, pp. 69-70); 1923 (Diamond, pp. 186-187); 1924 (Diamond, pp. 66-71).
The mineral resources of Maranhão, Brazil, by E. W. Shaw, W. H. Wright and J. L. Darnell; Econ. Geol., 1925, **20** (Diamond, pp. 725-726).
Estudo das jazidas de diamante de Bôa Vista, by D. Guimarães; Rel. Ann. do Director, Minist. da Agric., Ind. e Comm., for 1927, pp. 58-60.
O diamante no estado de Minas Geraes, by D. Guimarães, and Algumas jazidas de diamante no norte de Minas Geraes, by L. J. de Moraes; Serv. Geol. e Min. do Brasil, Bol. 24, 1927, 65 pp.
A geologia da região diamantina, estado de Minas Geraes, by L. J. de Moraes; Rel. Ann. do Director, Minist. da Agric., Ind. e Comm., for 1928, pp. 29-34.
Estudos sobre a rocha matriz do diamante, by L. J. de Moraes and D. Guimarães; Rel. Ann. do Director, Minist. da Agric., Ind. e Comm., for 1928, pp. 171-174.

Geologie und Diamanten im Staate Bahia, Brasilien, by O. Pratje; Schr. Phys.-ökon. Ges. Königsberg i Pr., 1928, **65**, 258-259.
The upland diamond deposits of the Diamantina district, Minas Geraes, Brazil, by L. S. Thompson; Econ. Geol., 1928, **23**, 705-723.
Historical notes on diamond mining in Minas Geraes, Brazil, by S. H. Ball: Min. and Met., 1929, **10**, 282-285.
Rock crystal and diamond pipes in Brazil, by R. R. Walls; Geol. Mag., 1929, **66**, 111-116.
Pedras preciosas e semi-preciosas do Brasil; Ann. do Minist. da Agric., Ind. e Comm., 1930, pp. 199-209.
The diamond deposits on the Upper Araguaya River, Brazil, by F. W. Freise; Econ. Geol., 1930, **25**, 201-207.
Mineral resources of Brazil, by E. P. de Oliveira; Serv. Geol. e Min. do Brasil, 1930 (Diamond, p. 6).
The diamond-bearing region of northern Minas Geraes, Brazil, by L. J. Moraes and D. Guimarães; Econ. Geol., 1931, **26**, 502-530.
Über die Diamantlagerstätten des Hochlandes von Diamantina, Minas Geraes, Brasilien, by C. W. Correns; Zeits. f. prakt. Geol., 1932, **40**, 161-168, 177-181.
Placer diamond mining in Brazil, by W. B. Stanley and B. E. Anderson; Min. and Met., 1932, **13**, 325-326.

Beryl and Emerald.

Relatorio do Serviço Geologico, Ministerio da Agric., Ind. e Comm., Rio de Janeiro, 1923 (Emerald, p. 188).
Emeralds at Bom Jesus dos Meiras, Bahia, Brazil, by E. Just; Econ. Geol., 1926, **21**, 808-810.
Mineral resources of Brazil, by E. P. de Oliveira; Serv. Geol. e Min. do Brasil, 1930 (Beryl and Emerald, pp. 6-7).
Aguas marinhas no Brasil, by L. C. Ferraz; Compendio de Mineraes do Brasil. Abstr. Bol. do Depart. Nac. do Comm., 1931, **1**, 70-71.
Beryllium minerals in Brazil, by L. J. Moraes; Econ. Geol., 1933, **28**, 289-292.

Other Gemstones.

On the mode of occurrence of topaz near Ouro Preto, Brazil, by O. A. Derby; Amer. Journ. Sci., 1901, **11** (4th Ser.), 25-34.
Brazil: a centenary of independence, 1822-1922, by J. C. Oakenfull; Freiburg, 1922 (Diamond, pp. 489-520; Topaz, pp. 579-584; Tourmaline, pp. 584-587).
The semi-precious stones of Brazil; Brazilian American, Rio de Janeiro, Dec., 1924. Abstr. Bull. Pan-Amer. Union, 1925, **59**, 371-380.
Nota sobre algumas jazidas de beryllo e mica do valle do Rio Doce, estado de Minas Geraes, by L. J. de Moraes; Serv. Geol. e Min. do Brasil, Bol. 18, 1926 (Tourmaline, p. 28).
Dept. Overseas Trade Rept. on economic conditions in Brazil to November, 1929; H.M. Stationery Office, London (Gemstones, p. 98).
Pedras preciosas e semi-preciosas do Brasil; Ann. do Minist. da Agric., Ind. e Comm., 1930, pp. 199-209.
Mineral resources of Brazil, by E. P. de Oliveira; Minist. da Agric., Ind. e Comm., 1930 (Gemstones, pp. 6-7).
Edelskapolith ein neuer Edelstein aus Brasilien, by H. Rose, W. F. Eppler, and A. Schröder; Deuts. Goldschmiede-Zeit., 1930, **33**, 438-439. Abstr., Mineralog. Abstr., 1932, **5**, 58.

CHILE.

Deposits of marble, onyx and lapis lazuli in Chile, by R. S. Smith; Stone Trades Journ., 1924, **42**, 310.

Colombia.

Emerald.

Emeralds: their mode of occurrence and methods of mining and extraction in Colombia, by C. Olden; Trans. Inst. Min. Met., 1911-12, **21**, 193-209.
The emerald deposits of Muzo, Colombia, by J. E. Pogue; Trans. Amer. Inst. Min. Eng., 1916, **55**, 910-934.
Informe del Ministro de Hacienda al Congreso, Bogota, Colombia, 1920 (Emerald, pp. lxxxii-lxxxiii); 1921 (Emerald, pp. lxi-lxii).
Colombia: Commercial and Industrial Handbook, by P. L. Bell; Bur. For. Domestic Commerce, Spec. Agents Ser. 206, Washington, 1921, pp. 250-251.
The republic of Colombia; Pamphlet issued by Colombia Govt. Bureau, London, 1923 (Emerald, p. 6).
Notes on emeralds in Colombia; Colombian Trade Rev., 1923, **3**, 132, 151, 243.
Rept. Dept. Overseas Trade on the industry and trade of Colombia, March 1924 (Emerald, p. 12); May 1925 (Emerald, p. 32); July 1929 (Emerald, pp. 57-58).
Das Smaragdvorkommen von Nemocón, by R. Scheibe; Neues Jahrb. f. Mineralogie, Abt. B., 1926, **53**, 321-324.
Die Smaragdlagerstätte von Muzo (Kolumbien) und ihre nähere Umgebung, by R. Scheibe; Neues Jahrb. f. Mineralogie, Abt. B., 1926, **54**, 419-447.
Beiträge zum Smaragdbergbau in der Republik Kolumbien, Südamerika, by G. J. Kellner; Zeits. f. prakt. Geol., 1927, **35**, 70-74.
Colombia Cafetera, by D. Monsalve; Printed for the Republic of Colombia, Barcelona (Emerald, pp. 679-681).
Minas de esmeraldas, by R. L. Codazzi; Bol. de Min. y Petról., Colombia, 1929, **1**, 114-143.
The Chivor-Somondoco emerald mines of Colombia, by P. W. Rainier; Amer. Inst. Min. Met. Eng., Techn. Publ. 258, Class H, No. 11, 1929, 21 pp.

Uruguay.

Gems and precious stones in 1918, by W. T. Schaller; U.S. Geol. Surv., Min. Res. U.S., 1918, Pt. 2, p. 10.

Venezuela.

Diamantlagerstätten in Venezuela, by F. Ahlfeld; Zeits. f. prakt. Geol., 1923, **31**, 76-77.
Gold and diamonds in Venezuela, by W. J. Millard; Min. and Met., 1931, **12** (Diamond, p. 399).
Vade mecum à l'usage des exportateurs et des voyageurs de commerce, by Régnier; Moniteur Offic. du Comm. et de l'Ind., Feb. 11, 1931 (Diamond, p. 582).

China.

General statement on the mining industry (1918-1925), by C. Y. Hsieh (in Chinese); Spec. Rept. No. 2, Geol. Surv., China, 1926 (Precious stones, pp. 336-8).
Mineral resources of Northern Manchuria, by E. E. Ahnert; Mem. Geol. Surv. China, 1929, Series A, No. 7 (Gemstones, p. 60).
The jade industry in China; Commerce Repts. (U.S. Dept. Comm.), March 17, 1930, pp. 692-694.
A trip in China, by F. L. Hess; Address to Washington, D.C., Section Amer. Inst. Min. Met. Eng., Jan. 20, 1930. Abstr. Min. and Met., 1930, **11** (Jade, p. 192).

INDO-CHINA.

Ruby and Sapphire.

Études minéralogiques sur l'Indochine française, by ('ŷy; Paris, 1913 (Ruby and Sapphire, pp. 103-105).
Les mines du Cambodge. Les mines de saphirs de Phi Vie Techn. et Ind., Special Indo-China No., 1922, pp. 111-112.
Le Cambodge économique, by E. D. de Campocasso; Bull. Écon. de l'Indochine, No. 162, 1923, pp. 355-411 (Sapphire, pp. 406-407).
L'industrie minérale en Indochine; Bull. Écon. de l'Indochine, 1925, **28**, 122-123; 1927, **30**, 690; 1928, **31**, 676; 1929, **32**, 903.
L'industrie minérale en Indochine; Insp. Gén. des mines, Hanoi, 1931 (Sapphire, p. 65).
Nos mines indochinoises en 1929-1930, by P. Cordemoy; Bull. de l'Agence Écon. de l'Indochine, 1931, **4** (Sapphire, p. 52).
La géologie et les mines de l'Indochine française, by F. Blondel; Paris, 1932 (Sapphire, pp. 95-96 and 130).

JAPAN.

Minerals of Japan, by T. Wada (translated into English by T. Ogawa); Tokio, 1904.

NETHERLANDS EAST INDIES.

Diamond.

Borneo: its geology and mineral resources, by T. Posewitz (translated by F. H. Hatch); London, 1892, pp. 381-406.
Aanhangsel hij de geologische overzichtskaart van den Nederlandsch Oost-Indischen Archipel, by L. J. C. van Es and G. Bouwmeester; Jaarb. v. h. Mijnw. in Nederl. Ooost-Indië, 1918, **47**, Trans., Part 2, 36-64 (Diamond, pp. 57-60).
Verslag over de resultaten van geologisch-mijnbouwkundige verkenningen en opsporingen in de residentie westerafdeeling van Borneo, by J. E. Loth; Jaarb. v. h. Mijnw. in Nederl. Oost-Indië, 1918, **47**, Trans., Part 1, 224-280 (Diamond, pp. 277-280).
Bijdrage tot de kennis van den oorsprong en de verspreiding der diamanthoudende afzettingen in Zuidoost-Borneo en van de opsporing en winning van den diamant, by L. H. Krol; Jaarb. v. h. Mijnw. in Nederl. Oost-Indië, 1920, **49**, Trans., Part 1, 250-304.
Dept. Overseas Trade Rept. on the economic situation of the Netherlands East Indies, to March 1922, p. 25; to June 1923, p. 78; to July 1924, p. 37; 1925-1926, p. 49.
Diamonds in Dutch Borneo, by A. S. Wheler and J. H. Foran; Mining Mag., 1923, **29**, 9-13.
The mineral wealth of the Netherlands East Indies; Handb. Netherlands East Indies, 1930 (Diamond, p. 257).
Diamond mining in Borneo, by S. H. Ball; Eng. Min. World, 1931, **2**, 706-708.
Yearbook of the Mining Industry in the Dutch East Indies (Annual).

(19661—8) Wt. 725—286 675 10/33 P. St. G. 3